[illegible] STUDY

BOTANY

HOME STUDY

BOTANY

Highland Park College

CORRESPONDENCE SCHOOL

DES MOINES, IOWA

BOTANY

SUGGESTIONS

1. **Plan of work.**—In the following lessons in botany the plan has been to arrange the topics in accordance with the logical development of the science, beginning with the simpler forms of plant life and proceeding to the more complex. In a few cases it has been found necessary to describe the minute structure of some plants, or parts of plants, in order that the function of the particular structure might be made clear.

2. **Illustrative material.**—With the exception of these few cases, all the facts given may be studied in connection with the actual objects. In no science is laboratory work so easy to carry out as in botany, and in none is it more necessary. The material for the work is close at hand and a large part of it, particularly in elementary work, is of such a nature that very little apparatus is needed. A sharp, thin-bladed knife and a pocket lens are all the apparatus which is necessary for the beginner.

For those who live in small towns and near the wooded districts, the material will not be difficult of access, but students living in larger communities may find some difficulty in obtaining the proper illustrative material, unless they happen to live in the vicinity of a vacant lot or two. These, even comparatively large cities possess in greater or less number, and it is quite remarkable what a wealth of material such a lot will offer. It may contain a few trees and shrubs, a vine or two, with some smaller

plants, and here will be found illustrations of bud arrangement, stem structure, pollination, the light relation, etc. If it presents some variations of conditions, such as uneven surface, with water supply in varied amount, and so on, the study of plant societies may be easily pursued on a small scale. For the keen observer and diligent searcher, enough material may be found in one such locality to illustrate many of the fundamental points of botany.

3. **References.**—The following are the names of a few books of reference which will be of value to those who may make use of these lessons. *Plant Studies* by John M. Coulter, of the University of Chicago (D. Appleton & Co.) is one of the best of the new texts on general botany. This book is a combination of two smaller texts, each of which may be obtained separately. The first one is called *Plant Relations* and is a study of ecology, and the second is entitled *Plant Structures*. *The Foundations of Botany* by Joseph Y. Bergen (Ginn & Co.) and *Elementary Botany* by G. F. Atkinson (Henry Holt & Co.) are two other texts intended for high school work. The *Text Book of Botany* by Drs. Strasburger, Noll, Schenck, and Schimper, of the University of Bonn, translated by H. C. Porter (The Macmillan Co.) offers material for more advanced study. A very simple, easily understood guide for plant analysis is found in the *Key to the Flora of the Northern United States* by Thomas H. Macbride of the University of Iowa (Allyn and Bacon).

Attention is called to the very full index which we have provided. By the large number of cross references it is made possible to find readily the information sought. We know that in their home study our students will appreciate the helpfulness of an index which saves valuable time and which also greatly enhances the interest of study.

LESSON I

GROUPS OF PLANTS. THALLOPHYTES

Botany is the science which attempts to answer every reasonable question about plants.—GOODALE.

4. **Similarity between plants and animals.**—There is no definite line of distinction between the lower plants and lower animals. All differences usually given are superficial and erroneous. The statements generally made are that plants are unlike animals because they are immovable, insensible, are possessed of green color, feed upon simple inorganic substances, and have not the power of respiration.

But plants are (1) keenly sensitive to certain conditions, such as temperature and moisture. (2) They are not all immovable; many lower plants have a translative power, while higher plants have power to move certain organs. (3) The green color is not found in all plants, all the fungi and some others lack it entirely. (4) Some plants do live on simple inorganic substances, but the fungi are capable of living on very complex organic substances which they obtain from decaying materials. (5) The respiratory action of plants is very similar to that of animals, oxygen being taken in and carbonic acid gas thrown off, energy being liberated during the process.

The fundamental similarity of animals and plants is the likeness of the living substance of both, the protoplasm.

THE PLANT CELL

5. **The unit of structure.**—The cell is the unit of plant structure. The bodies of the simplest plants consist of but one cell, while the bodies of the most complex plants consist of very many cells.

6. **Parts of a cell.**—The usual shape of the cell, if free, is spherical. The parts of a cell are (1) the cell wall, (2) living substance, the protoplasm, (3) the nucleus, (4) cell sap.

(1) The cell wall is a thin jacket around the cell, made of a substance called cellulose.

(2) The protoplasm is a semifluid substance which is in appearance and thickness much like the white of an egg. When seen in the living plant it is in constant motion in the cell, traveling up one side and down the other. It has many properties:

(a) It has the power to take up new materials into its own substance. This is not merely of soaking up liquids, but the selection of some substances and rejection of others. This is *selective absorption.*

(b) It has power to change certain substances into others of different chemical composition. This is *metabolism.*

(c) It has the power to cast off waste materials.

(d) It has capacity for growth and reproduction. These are especially characteristic of active protoplasm.

(e) It is sensitive when touched or otherwise disturbed, as by a change of light or temperature.

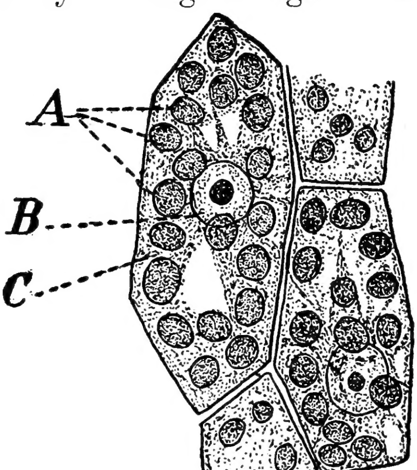

Fig. 1. Cells from a moss leaf, showing nucleus (*B*) in which there is a nucleolus, cytoplasm (*C*), and chloroplasts (*A*).—Caldwell.

From Coulter's Plant Structures. Copyright, 1899, by D. Appleton & Co.

(3) The nucleus is a thickened portion of the protoplasm. It is the most important part of the cell. That part of the protoplasm outside the nucleus is called the *cytoplasm.*

(4) The plant cell is not filled with protoplasm, but has a lining of it and inside of this is the cell sap, which is water holding in solution the food elements required by the plant, either in a crude or elaborated form.

THE GREAT GROUPS OF PLANTS

Even the casual observer will note that plants differ very much in structure. Some are simple, others complex, and the former are regarded as of lower rank.

7. **Names of groups.**—Four great groups of plants are known, each group representing certain stages in the gradation from lower to higher rank. The names of the groups are:

(1) Thallophytes.—The name means *thallus plants.* In this group are included some of the simplest forms, the algæ and the fungi.

(2) Bryophytes.—The name means *moss plants.* Here are placed the liverworts and the mosses.

(3) Pteridophytes.—*Fern plants.* Here are placed the ferns, club-mosses, and horsetail rushes.

(4) Spermatophytes.—*Seed plants.* These last are our most familiar plants and are commonly spoken of as *flowering plants.* They are highest in rank and most conspicuous and hence have received much attention.

8. **Cryptogams.**—The Thallophytes, Bryophytes, and Pteridophytes are often classed together under the term *Cryptogams,* which means that they are all *flowerless plants.* Nearly all of them, excepting only the simpler forms, reproduce by means of a body called *a spore.* A spore is a single cell set aside for the purpose of reproduction; a much simpler form of reproduction than a seed.

Spores are produced in two ways, either (1) *asexually,* from the protoplasm of some part of the plant, or (2) *sexually,* by the combination of two sex elements, two masses of protoplasm from two separate plants or from different parts of the same plant.

9. **The evolution of plants.**—It is generally supposed that the more complex plants have descended from the simpler ones, that the Bryophytes have been derived from Thallophytes, and so on. All the groups, therefore are supposed to be related in some way. This theory of the relationship of plant groups is known as evolution. To

well understand any higher group one must study the lower ones related to it. We present a careful study of some types of the subgroups.

THALLOPHYTES

10. **Algæ.**—Algæ are generally defined (1) as plants possessing *a thallus,* which is a vegetative or nutritive body, having neither true root, stem, nor leaves; and (2) as possessing *chlorophyll,* which is the green coloring matter of plants. Algæ are found in water or damp places.

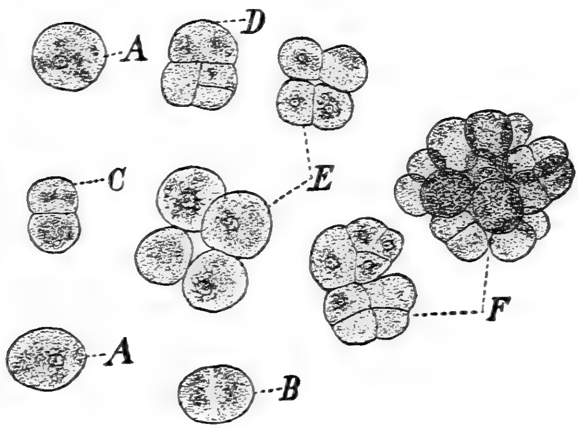

FIG. 6. *Pleurococcus,* a one-celled green alga : *A*, showing the adult form with its nucleus; *B, C, D, E,* various stages of division (fission) in producing new cells; *F*, colonies of cells which have remained in contact.—CALDWELL.

11. **Pleurococcus.**—This is a one-celled alga plant. It is commonly found in masses covering damp tree trunks and on the sides of buildings in damp localities, and looks like a green stain. These masses are made up of multitudes of spherical cells, which may be solitary or may cling together in groups. The finely granular green portion of each cell is the chlorophyll. In this plant we have illustrated the simplest form of reproduction of plant bodies, *cell division.* Each cell divides and forms two new cells, each of the two forms two others, and so on.

12. **Spirogyra.**—This is one of the commonest of algæ. It is found in ponds, slow running streams, and in watering troughs. It may be recognized by its threadlike structure, brilliant green color, and slippery feeling.

Each of the threadlike portions or filaments is made up of a number of cells, joined end to end. In the cells are remarkable chloroplasts, or chlorophyll bearing bodies, which are bands passing spirally around the cell.

In its life history *spirogyra* represents the beginnings of reproduction by sex elements, or gametes, as they are called. Two filaments lying side by side, put out tubular processes toward one another. When the tips of two such processes come together, the end walls disappear, and a continuous tube extending between the two cells is formed.

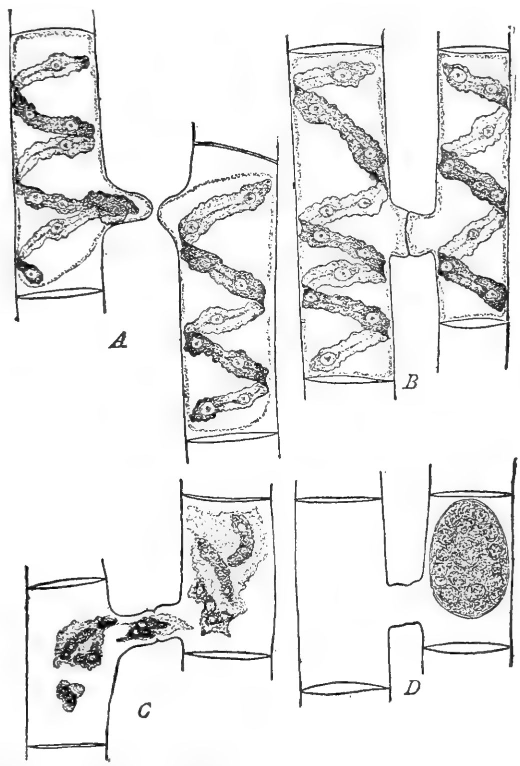

FIG. 14. *Spirogyra*, showing conjugation: *A*, conjugating tubes approaching each other; *B*, tubes in contact but end walls not absorbed; *C*, tube complete and contents of one cell passing through; *D*, a completed zygospore.—CALDWELL.

While the connecting tube is being developed, the contents of the two cells thus being united are organizing, and after the completion of the tube, the contents of one cell pass through and enter the other cell, fuse with its contents and a sexual spore is formed. This spore is well adapted to withstand changes in seasons, and is in reality a resting spore. At the beginning of each growing season, the resting spores germinate directly into new spirogyra filaments.

13. **Other forms of algæ.**—Many other forms of algæ exist. The two forms described belong to the green algæ. The other great alga groups are the blue-green, the red, and the brown algæ. In the last three groups, chlorophyll is present, but is masked by other coloring substances in the plant. The green and blue-green algæ are characteristic of fresh water, but the red and brown algæ are found, with a few exceptions, in salt water. The beautiful *sea weeds* of our coasts belong to these groups.

14. **Fungi.**—In general, the fungi are Thallophytes which do not possess chlorophyll. As chlorophyll is the element by means of which the plant is enabled to manufacture its food, it follows that these plants cannot manufacture food out of inorganic material, but are dependent for it upon other plants, or upon animals. This food is obtained in two ways, either (1) directly from the living bodies of plants or animals, or (2) from dead bodies or the products of living bodies. Those which belong to the first class are called *parasites,* and the plant or animal class are called *saprophytes.*

Some fungi can live only as saprophytes, or as parasites, but some can live in either way.

15. **Economic value of fungi.**—The fungi are much more numerous than the algæ. Many of the parasites attack and injure useful plants and animals, producing many of the so-called *diseases* and so are objects of great interest. Not all of the fungi, however, are harmful, many of the parasitic forms being harmless, while many of the saprophytic forms are decidedly beneficial.

16. **Plan of structure.**—Setting aside certain forms, such as yeast and bacteria, the bodies of all true fungi are organized upon a general plan. The main part of the plant consists of a mass of branching filaments, called the *mycelium*. This may be a loosely interwoven mass; or it may be close and compact, forming a feltlike mass, as may often be seen in the mould upon preserved fruits. This mycelium is in contact with the source of food supply. The threads of the mycelium are known as *hyphae* (singular hypha). Those which are vertical, are set apart to produce the asexual spores, which are scattered and produce new mycelia. These branches are called ascending hyphæ.

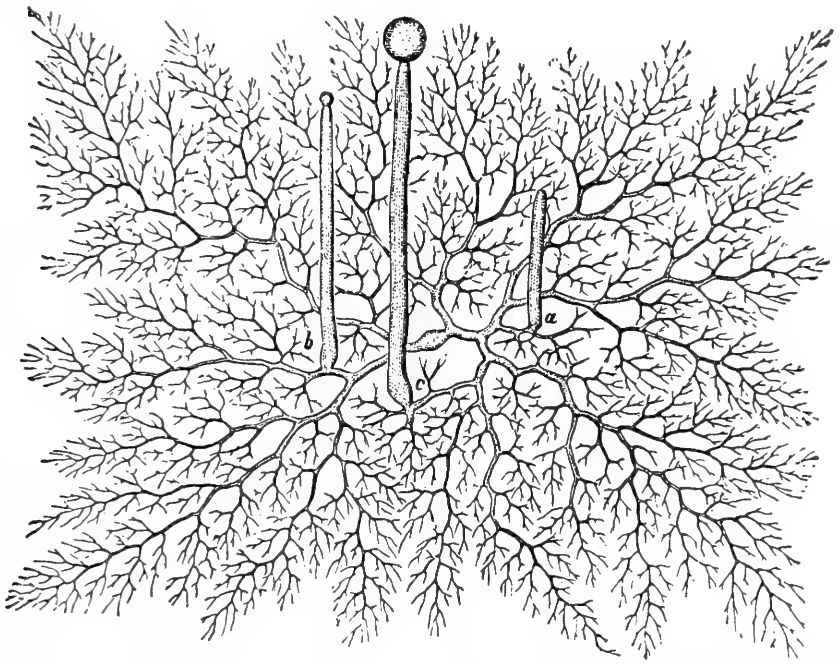

FIG. 32. A diagrammatic representation of *Mucor*, showing the profusely branching mycelium, and three vertical hyphæ (sporophores), sporangia forming on *b* and *c*. —After ZOPF.

17. **Black mould.**—This is one of the most common of the fungi and may be found growing in abundance on

decaying fruits or vegetables, on damp bread, or on manure heaps.

On mouldy bread the slender, threadlike network of the mycelium may be seen with the naked eye, or with a simple hand lens. The delicate threads, arising at intervals from the mycelium, are the ascending hyphæ. On the tips of these are found tiny black dots. These little spheres are the *sporangia* or spore cases, each a transparent sac packed full of black spores. The reproduction is brought about by means of the spores, which are scattered through the air when the sac is ruptured, and which, when they light upon some organic matter, grow, producing new mycelia.

18. **Chemical action.**—When mould acts upon any substance, such as bread, that substance is consumed by the mould. The bread shows this by its change in taste, giving evidence of chemical change undergone in its substance. In canned fruit, if the process continues for a long time, little is left but water.

19. **Mushrooms and puffballs.**—This group includes also the toadstools, which are not botanically distinct from mushrooms. These are the most highly organized of the fungi. They are not destructive parasites, but mostly harmless and often useful saprophytes.

20. **Mushrooms.**—A common mushroom consists of a mycelium of white branching threads, spreading extensively through the substratum of decaying leaves and grass. Upon this mycelium little buttonlike knobs begin to arise, growing larger and larger until they are formed into the part which we call the mushroom, and which is simply the fruiting portion of the plant. The mushroom is composed of two parts, the stalklike portion or stipe, and the expanded cap or *pileus.* On the under surface of the pileus hang great numbers of plates or gills, radiating from the center. Each gill is a compact mass of hyphæ, whose tips bear the spores by means of which the plant is reproduced.

21. **Puffballs.**—The puffballs have their fruiting portion in the form of globular bodies, within which the spores develop and which are set free only when ripe.

22. **Bracket fungus.**—Another form of this division of the fungi is found in the bracket or shelf fungus, which forms shell-like outgrowths on tree trunks, stumps, and posts.

23. **Rusts, mildews, and smuts.**—These groups may be illustrated by the fungus attacking wheat, producing the wheat rust, the fungus attacking the grape, producing grape mildew, and the one attacking corn, producing corn smut. The *rust, mildew,* and *smut* represent mainly the fruiting portion of the plant, being accumulations of spores and spore-bearing portions. The hyphæ of these forms penetrate the tissues, causing in many cases vast injury to the plant. So these are among the most harmful of the parasitic fungi.

All of these forms have very complicated and obscure life histories, and no indication of a sexual process of reproduction has been noted in them.

24. **Yeast.**—Yeast is a one-celled fungus plant, of microscopic size. In its wild form it is found in the ground around apple trees, grapevines, etc. The form which is of economic importance is a cultivated plant. Yeast will grow only in solutions containing sugar. The presence of yeast in a substance may be determined by the bubbles of gas arising from the liquid, by the sharp odor due to the presence of alcohol, and by the yellowish sediment.

25. **Fermentation.**—In performing its functions yeast brings about *fermentation* in substances. Fermentation is the changing of sugar to alcohol and a gas called carbon dioxide. The gas is liberated from the mixture in the form of bubbles, and the alcohol remains in the liquid. When yeast acts upon the juices of certain plants which contain sugar various alcoholic liquors, as wine and whisky, are formed.

Fig 68. A group of Bacteria, the bodies being black, and bearing motile cilia in various ways. *A*, the two to the left the common hay *Bacillus* (*B. subtilis*), the one to the right a *Spirillum*; *B*, a Coccus form (*Planococcus*); *C, D, E*, species of *Pseudomonas*; *F, G*, species of Bacillus, *F* being that of typhoid fever; *H*, *Microspira*; *J, K, L, M*, species of *Spirillum*.—After Engler and Prantl.

26. **Bread making.**—In bread making, yeast acts upon the sugar present in the grains, and causes the formation of carbon dioxide and alcohol. Wheat flour contains a large amount of a substance called *gluten*, which is very sticky, and serves to make cavities in which the gas is imprisoned, thus causing the *lightness* of the bread. When baked all the yeast plants are killed and the alcohol is evaporated by the action of the heat of the oven, thus leaving a wholesome product.

The growth of the yeast plant is promoted by a moderate degree of warmth, and by the proper per cent of sugar. It cannot grow in pure water or in pure syrup.

27. **Bacteria.**—The bacteria form one of the important groups of the fungi. They are remarkable because of their extreme minuteness and of their extraordinary power of multiplication.

They are the smallest known living organisms, and multiply by cell division with wonderful rapidity. They also form resting spores for distribution and preservation. They occur everywhere, in the air, in the water, in the soil, in the bodies of animals and plants. Many of them are harmless, many of them useful, and many of them dangerous.

They are of various forms, as bacilli forms, short rod shaped cells, spirillum forms, spiral filaments, cocci forms, in shape of spheres, and the like.

28. **Bacteria as agents of decay.**—Under the head of beneficial effects of bacteria may be stated their work in producing decay in the tissues of dead animals and plants. If it were not for the destructive action of these bacteria, all the food materials needed by other organisms would be locked up in the form of dead tissues to cumber the earth, and after all the available material had been thus locked up, there could be no food supply for plants and animals.

29. **As agents of nitrogen fixation.**—Bacteria are beneficial also in enriching the soil that lacks nitrogen, an element which plants must have for their food, and which, although it exists in great quantities in the air, they are

not capable of using, except as it is found in solution in the water which they obtain from the soil. Certain plants, as the clover, bean, and pea, together with other plants belonging to the order *leguminosæ*, have attached to their roots colonies of bacteria, and these bacteria have the power to take nitrogen from the air contained in the soil, and to fix it in their own bodies. When they die and decay, the plant to which they are attached can make use of the nitrogen. During this time the bacteria are doubtless obtaining food from the roots of the plant, but without apparently injuring it.

This habit of clover and its allies explains why they are useful in what is called *restoring the soil*. After ordinary plants have used all the nitrogen containing salts, and the soil has become somewhat sterile, clover can grow upon it by obtaining its nitrogen from the air through the aid of the bacteria. If the clover is plowed under the decay of the plants gives to the soil the nitrogen necessary for the growth of other plants. The presence of the bacteria upon the roots of the clover and allied plants is indicated by *tubercles*, which are excrescent growths caused by the bacteria.

30. **Bacteria and cheese.**—One of the minor points in which bacteria are useful is in producing the flavor of cheese. Each particular variety of cheese owes its flavor to a certain class of the bacteria, which develops in its substance during the ripening process. Many varieties of cheese can be produced only in certain localities, favorable to the particular bacteria which produce their flavors. Some of the foreign varieties of cheese, however, are now produced in America, by taking the imported cheeses and rubbing the shelves of the ripening rooms with them, by which means the bacteria obtain a foothold for growth.

31. **Bacteria and disease.**—The pathogenic forms, that is, those which produce diseases of plants and of animals, are of great importance, and means of making them harmless or destroying them are being searched for constantly. These are the parasitic forms, and one or two

examples will serve to illustrate how they find a lodgment in the host.

Sewage water often swarms with the bacillus of typhoid fever. The people in the city drink unfiltered water into which sewage has been allowed to run higher up the stream, the bacilli multiply at a rapid rate in the intestines of those who have drunk the water, and many of them are taken sick with typhoid fever. Also, the phlegm

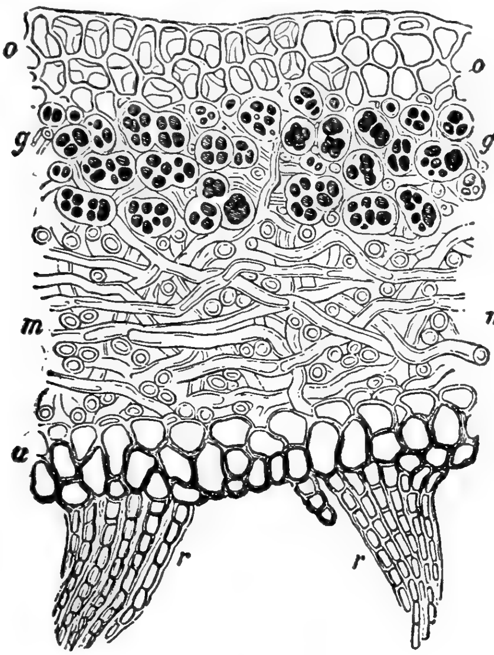

FIG. 72. Section through thallus of a lichen (*Sticta*), showing holdfasts (r), lower (u) and upper (o) surfaces, fungus hyphæ (m), and enmeshed algæ (g).—After SACHS.

expectorated by consumptive patients is full of the consumption bacillus. This phlegm becomes dried on floors, streets, or sidewalks, it is breathed by everyone in the form of fine dust, and in the lungs of many who breathe it, colonies of harmful bacilli are formed and thus the disease becomes established in these persons.

The diseases caused by bacteria are not a result of the presence of the bacteria in the body, but of the destructive

effect of certain bacteria upon the tissues, producing poisons called *toxins*. These poisons, it is inferred from certain experiments, are neutralized by certain *antitoxins* which the blood has the power of forming. The production of the antitoxin is thus apparently a distinct reaction of the body to the stimulus of the toxin in such a way as to neutralize its bad effect, provided the vitality of the tissues has not been already too far lowered by an overwhelming amount of toxin.

32. **Lichens.**—Lichens are abundant everywhere, forming various colored spots on the trunks of trees, rocks, and old boards, and growing also upon the ground. They have a general grayish color, but brighter colors may also be observed. Some are possessed of a leafy structure, others grow as if they formed part of the bark or rock to which they are attached.

The great interest connected with lichens is that they are not single plants, but each lichen is formed of a fungus and an alga, living together so intimately as to appear like a single plant. The fungus makes the bulk of the body, with its interwoven mycelial threads in the meshes of which lie the one-celled alga plants.

These two plants are thought by some to be mutually helpful, the alga manufacturing food for the fungus, and the fungus providing protection and water containing food materials for the alga. Others do not recognize any special benefit to the alga, but see in a lichen simply a parasitic fungus living upon the products of an alga. In any event, the algæ are not destroyed but seem to thrive.

QUESTIONS

1. In what ways are plants and animals similar?
2. Upon what is the fundamental similarity of plants and animals based?
3. What is a cell? What are the parts of a cell?
4. What is protoplasm? What are its most important properties?

5. What is the nucleus? Cytoplasm? Cell sap?

6. What does the picture on page 4 show?

7. What are the great groups of plants?

8. What are cryptogams? How do the cryptogams reproduce? What is a spore?

9. What is meant by the evolution of plants?

10. What are algæ? Where is pleurococcus found? What is its appearance? How does it reproduce?

11. What is the leading purpose of the picture on page 6?

12. Where is spirogyra found? How does it reproduce?

13. What distinct steps are illustrated in the picture on page 7?

14. What are some of the other forms of algæ? Where found?

15. What is chlorophyll? Why is its presence sometimes not apparent?

16. What are fungi? How do they obtain their food? Why do they not obtain it in the same manner as the algæ? What is a parasite? A saprophyte?

17. What is the general plan upon which most of the true fungi are organized? What plants of this group are exceptions to this plan?

18. From the picture on page 9 do you get a clear idea of the sporangia?

19. What is black mould? Where found? How does it reproduce? What are sporangia?

20. Describe a common mushroom. How do mushrooms reproduce? What is the toadstool?

21. What are puffballs? What are bracket fungi?

22. What are rusts, mildews, and smuts? What is the economic importance of this class of the fungi?

23. What is yeast? How is its presence in a substance determined? What is fermentation? How is wine made? What is the use of yeast in bread making? What conditions are necessary for the growth of the yeast plant?

24. What are bacteria? What is said of their size? How do they reproduce? What are resting spores and why do the bacteria form them?

25. What does a careful study of the picture of page 12 disclose?

26. Where are bacteria found? What are some of the forms they exhibit?

27. What are some of the beneficial effects of bacteria? What is the necessity of decay? Why does clover restore the soil of a field in which it grows?

28. In what way are bacteria harmful? How do they find lodgment in their hosts?

29. To what are the diseases caused by bacteria due? What are toxins? What are antitoxins?

30. What are lichens? Where found? Of what is a lichen composed? What is the probable significance of the two plant forms thus united?

31. Do you derive a good impression of the holdfasts, the fungus hyphæ, and the enmeshed algæ, shown in the picture on page 15?

32. Why is it desirable to boil drinking water?

33. Why are foods preserved by canning?

34. Why is cold storage a means of food preservation?

35. Why will mould not grow on clean sand or in pure water?

36. Why does mould grow on bread and fruit? Why does it not have chlorophyll?

37. Lichens are often found growing on a tree. Do they damage the tree? Why not?

38. Why do mushrooms and other fungi expose to the air their spore bearing portions?

LESSON II

BRYOPHYTES. PTERIDOPHYTES. BUDS

33. **Classes of Bryophytes.**—Under this head are classed the liverworts and the mosses. Both of these classes consist of plants much more highly organized than the Thallopytes. Bryophytes have no true roots, but have organs which perform the work of roots. Some of them have leaves, while others have none. They have no true woody structure, such as is found in plants of still higher groups. There are chlorophyll bodies present in all of them.

34. **Reproduction.**—Reproduction is of two kinds, sexual and asexual, and the organs by which it is carried on are complicated and highly organized. In the life history of each class there is exhibited what is known as *alternation of generations.* That is, each plant during its life cycle really has two different forms; one which is produced by the union of two sex elements or gametes, and one which arises from an asexual spore. This asexual spore is produced by the plant which arises from the sexual union.

35. **Liverworts.**—Liverworts live in a variety of conditions, some floating on the water, many in damp places, and many on the barks of trees. There are three great classes of liverworts, but the species are numerous in only the first two classes. The one which will be described belongs to the first class, but to the second in importance, from the standpoint of the number of species.

36. **Marchantia polymorpha.**—This is one of the most common and familiar of the liverworts. It is a flat, ribbon-like, green little plant, found commonly creeping

over moist, cool soil in shady places. It is also common in greenhouses.

The plant body consists of a flattened leaf-like portion, a thallus, with its green color slightly darker above than

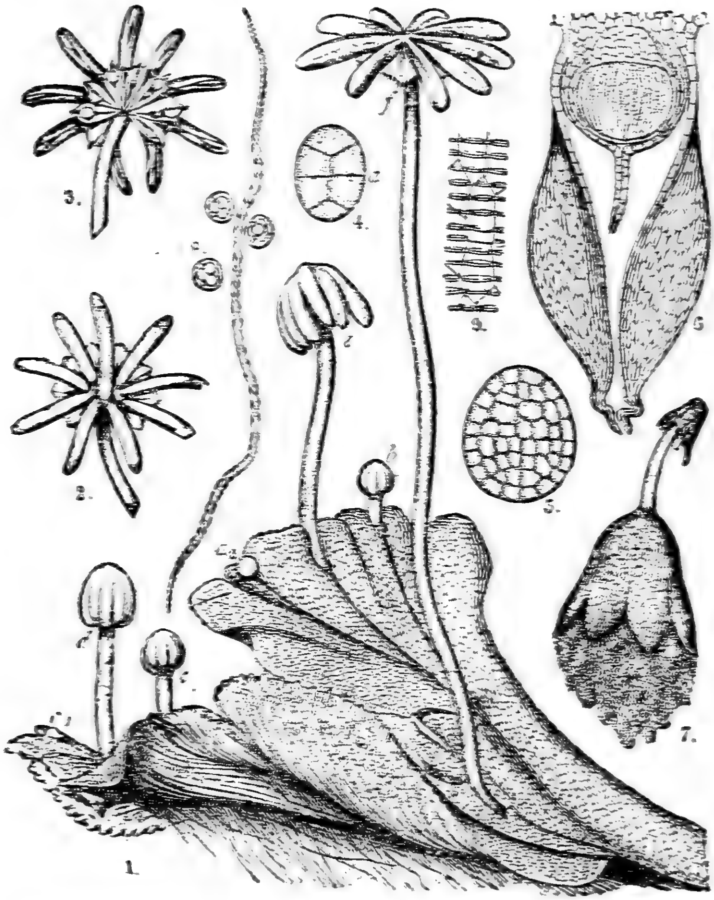

FIG. 97. *Marchantia polymorpha*, a common liverwort: *1*, thallus, with rhizoids, bearing a mature archegonial branch (*f*) and several younger ones (*a*, *b*, *c*, *d*, *e*); *2* and *3*, dorsal and ventral views of archegonial disk; *4* and *5*, young sporophyte (sporogonium) embryos; *6*, more mature sporogonium still within enlarged venter of archegonium; *7*, mature sporogonium discharging spores; *8*, three spores and an elater.—After KNY.

below. The upper surface is marked off in diamond shaped areas, and in the center of each is a minute opening or *stoma* (plural stomata). Along the under surface

of the thallus are root-like structures called *rhizoids,* which attach the plant to the substratum.

On the upper surface of the thallus are found conspicuous shallow cups, in which lie small green bodies visible to the naked eye. The cups are called *cupules,* their contents, *gemmae.* These gemmæ are simply buds, and a drop of water is sufficient to float them from the cupules. Once they find lodgment on suitable soil, each one is capable of developing a new plant.

On some of the portions of thallus are found very different sorts of structures. These are of two kinds, and are the reproductive bodies concerned in the sexual reproduction. One has a short stalk and a concave, disc-like top with crenulated edges. This is called the *antheridial disc,* and has in it numerous minute sacs called *antheridia,* in which the fertilizing cells are developed. These fertilizing cells are called *spermatozoids* and are the male or fertilizing elements. They are single cells, bearing a number of hair-like processes on the end, by means of which they are enabled to move through water.

The other reproductive body has a somewhat longer stalk, and a star-shaped or radiate disc. This is called the *archegonial disc.* On the under surface of the rays of this disc are found little flask-shaped bodies, placed with the neck downward, and these are called *archegonia.* These archegonia contain the female element, the oosphere, which awaits fertilization.

The process of fertilization is as follows: In April or May the antheridial cells have their walls upturned, and the spermatozoids escape and swim to the archegonial discs. They are so minute that dew or any small amount of water will furnish sufficient water for their passage. They are supposed to be directed in their course by chemical attraction between them and the female cell. Reaching the archegonial disc, they pass into the neck of the archegonium, and unite with the oosphere, producing a single cell called an oospore. From this oospore is developed by cell divisicn, a sporogonium, a type of spore case

peculiar to Bryophytes. This sporogonium contains besides a great number of spores, a number of threads called *elaters.* These are delicate thread-like organs, which twist and squirm under the influence of moisture, and help to scatter the spores.

The alternation of generations is as follows: The spore gives rise to the thallus which bears the branches, this is one generation, the oospore gives rise to the sporogonium, with its spores, the second generation. That alternation of generations is of great advantage is evidenced by the fact that it appears in all the higher plants. It does not really commence in the Bryophytes, but its beginnings may be seen in the Thallophytes. The full benefit of this alternation of generations is not known, but one advantage seems prominent, and that is, that by this means the product of the sexual spore is multiplied, and thus gives the species a better chance in the struggle for existence.

It is plain that if there were no alternation of generations, each sexual spore would produce but a single plant, but through the agency of this alternation many sexual spores are produced, each of which may give rise to a new individual.

37. **Mosses.**—Mosses are highly specialized plants, probably derived from liverworts, the numerous forms being adapted to all conditions from submerged to very dry, being found most abundantly in the temperate and arctic regions.

They have the power of reproduction by simple multiplication of the vegetative portion of the plant, new leafy shoots putting out from old ones indefinitely, forming thick masses. Certain forms thus completely fill up bogs or small ponds with a dense growth, which dies below and continues growth above so long as conditions are favorable. The lower layers of the moss in these bogs, instead of decaying, become modified into a coaly substance called peat.

The spore in the case of the moss plant, instead of developing a thallus, sends out a thread-like structure, made

up of chlorophyll bearing cells, and which branches again and again until a dense felt-like mass, covering considerable space, is formed. This is the *protonema* or *first thread,* and corresponds to the thallus of the liverwort. Upon this protonema, at intervals, are produced buds which give rise to the moss plants. These are erect, having rhizoids to hold them in the soil, and bearing leaves which are arranged about a central stem. The archegonia

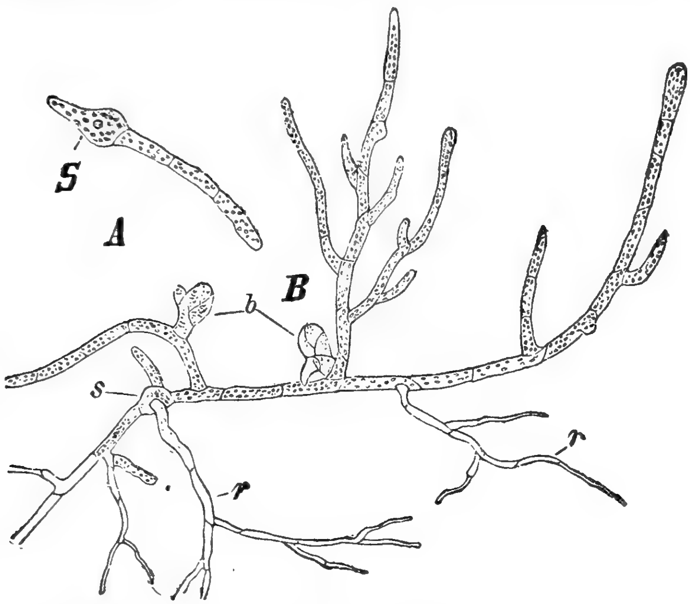

FIG. 81. Protonema of moss: *A*, very young protonema, showing spore (*S*) which has germinated it; *B*, older protonema, showing branching habit, remains of spore (*s*), rhizoids (*r*), and buds (*b*) of leafy branches (gametophores).—After MÜLLER and THURGAU.

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and antheridia are produced in little rosettes of leaves at the top of the stems of the plants, and the process of reproduction is similar to that of the liverworts.

In the mosses, however, the oospore gives rise to a somewhat different form of sporogonium. From the leafy rosette a long stem is sent out, which bears on its tip an oval body called *a capsule,* having a lid by which it opens. This capsule contains the spores. There are no elaters present in mosses. On some of the common mosses a little

cap, which is the remains of the old archegonium, in which the fertilizing cell was borne, is found fitting over the capsule. When the lid of the capsule falls off, a circle of tooth-like structures is seen around the mouth of the capsule. These teeth are susceptible to changes in moisture, and by bending backward and forward under the influence of these changes, help the spores to escape.

PTERIDOPHYTES

38. **The ferns.**—The ferns are the most numerous and most representative of this group. They well deserve to stand as types, for they contain about four thousand of the four thousand five hundred species belonging to the Pteridophytes. Although found in considerable number in the temperate regions, their chief display is in the tropics, where they form a striking and characteristic feature of the vegetation. Many of the low forms are to be seen in the tropics, and also tree forms with trunks rising to a height of thirty-five to forty-five feet, bearing leaves fifteen to twenty feet long.

39. **Horsetail rushes and club-mosses.**—Associated with them, are the horsetails (scouring-rushes) and club-mosses. The horsetails are represented by but a few forms, and their jointed stems and harsh texture have made them familiar objects to many. The club-mosses are represented by a greater number of forms, one group of forms, selaginella, being found in greenhouses as delicate, decorative plants, another called lycopodium furnishing our Christmas *greens.*

Both horsetails and club-mosses are representatives of groups which were very abundant during the coal measures, and helped to form the forest vegetation.

40. **Appearance of the vascular system.**—One of the most important facts in connection with the Pteridophytes is the appearance of a *vascular system,* which is a system of vessels forming the woody tissue of the plant, and organized for conducting material through the plant body.

The appearance of this system is of as much importance in the plant kingdom, as is the appearance of a backbone in the evolution of animals. As animals are classed as *vertebrates* and *invertebrates,* so plants are grouped as *vascular* and *non-vascular,* the former being the Pteridophytes and Spermatophytes, the latter being the Thallophytes and Bryophytes.

Alternation of generations continues in the Pteridophytes, but is even more distinct than in the Bryophytes. This can be shown by a study of the life history of any common fern.

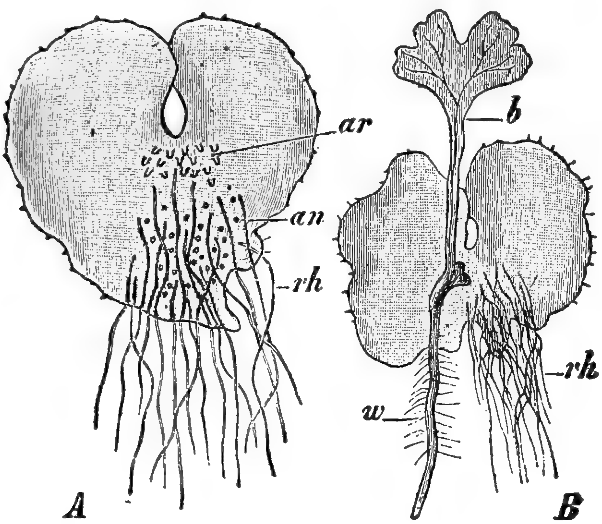

FIG. 111. Prothallium of a common fern (*Aspidium*): *A*, ventral surface, showing rhizoids (*rh*), antheridia (*an*), and archegonia (*ar*); *B*, ventral surface of an older gametophyte, showing rhizoids (*rh*) and young sporophyte with root (*w*) and leaf (*b*).—After SCHENCK.

41. **Study of the common fern.**—On the back of the leaves of ferns, at the fruiting season, are found dark spots or lines. These yield spores. When one of these spores germinates it gives rise to a small, green heart-shaped thallus. This is called the *prothallium,* and is often a quarter of an inch or more in diameter. These can often be found growing on the surface of the soil in pots of greenhouse ferns. Upon this prothallium the antheridia and

archegonia appear, the spermatozoids are liberated as in the liverworts and mosses, and enter the archegonia, fuse with the oosphere and form the oospore. When this oospore germinates it develops the large leafy plant ordinarily spoken of as the *fern*, with its subterranean stem from which the roots descend. It is in this complex body that the vascular system appears.

Each leafy portion of the fern is called a *frond*, and the subdivisions are *pinnae* (singular pinna). On the under side of the pinnæ the fruit dots or *sori* (singular sorus) are found.

Each sorus is composed of a number of sporangia and a little membranous covering called the *indusium*. In the common brake fern (pteris) and in the maidenhair there is no indusium, but the sporangia are covered by the incurved edge of the fronds.

Each sporangium is a little oval body, borne on a stalk, and having a special apparatus for the distribution of the spores, and these spores in turn give rise to new prothallia.

Two facts are characteristic of ferns, one is the manner of branching of the veins in the frond, the peculiar forked character of the veining being very conspicuous, the other is the manner in which the leaves in expanding seem to unroll from the base, as though they had been rolled from the tip downward. This habit is spoken of as *circinate*, from a word meaning *circle* or *coil*.

SPERMATOPHYTES

42. **Importance of the group.**—This group has often been studied alone as *botany*, to the exclusion of the other groups. This is because they are most conspicuous of all plants, and because they are greater in number and display than the other groups. The lower groups must be studied, not only to give a general view of the plant kingdom, but because a knowledge of their structure and functions is essential to an understanding of the structures of the highest group.

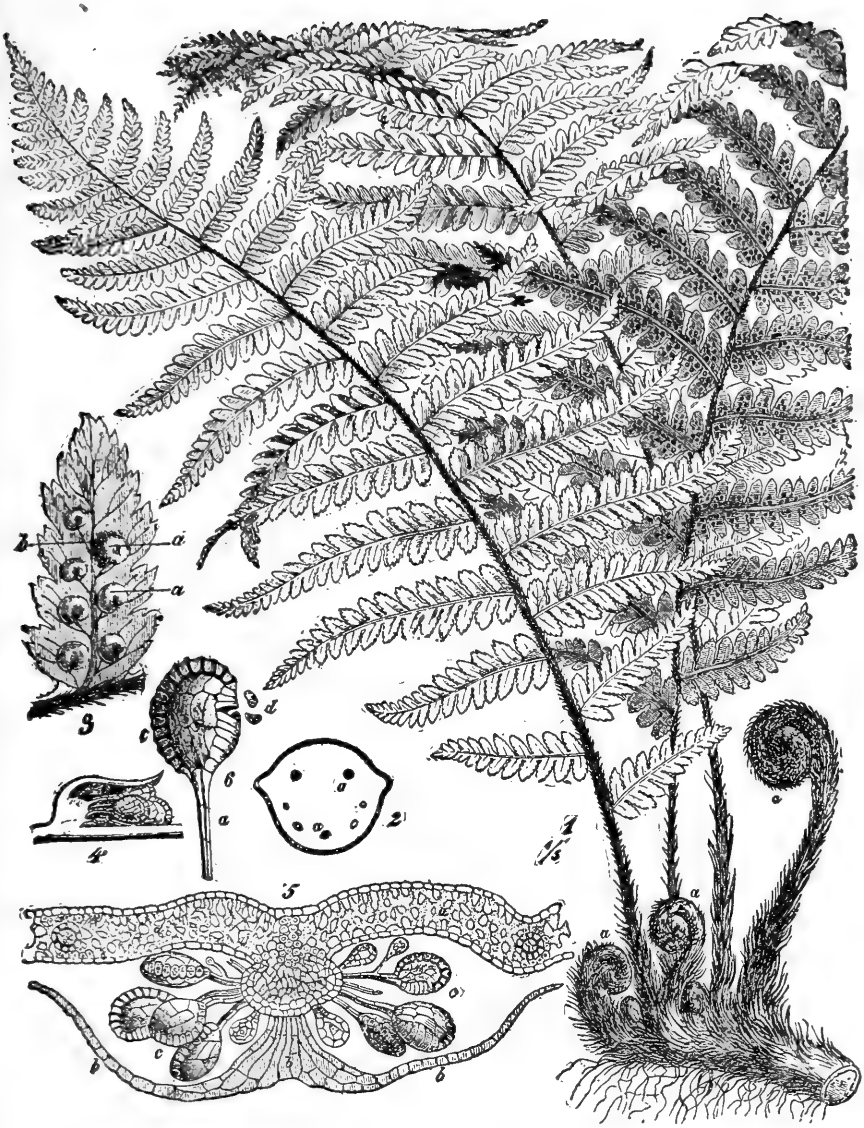

FIG. 118. A fern (*Aspidium*), showing three large branching leaves coming from a horizontal subterranean stem (rootstock); young leaves are also shown, which show circinate vernation. The stem, young leaves, and petioles of the large leaves are thickly covered with protecting hairs. The stem gives rise to numerous small roots from its lower surface. The figure marked *3* represents the under surface of a portion of the leaf, showing seven sori with shield-like indusia; at *5* is represented a section through a sorus, showing the sporangia attached and protected by the indusium; while at *6* is represented a single sporangium opening and discharging its spores, the heavy annulus extending along the back and over the top.—After WOSSIDLO.

The plants of this group are called Spermatophytes (seed plants) because the most distinguishing mark of the group seems to be the production of seeds. These plants follow the Pteridophytes without any sharply defined barrier, representing of course more highly developed forms. Their more advanced development is limited to the asexual generation, the plant body as a whole being in this stage, while the sexual generation has been reduced to a few cells found in the seed, and dependent upon the other generation for existence. This change in the relation between the two generations has been brought about gradually. Through successive stages from lower to higher forms the asexual generation, which at first was of smaller size, becomes the larger, and the reverse is true of the sexual generation.

The reproduction of this class of plants will be better understood after some study of the flower and the other characteristic organs.

BUDS

43. **Dissimilarity of trees.**—Comparing a number of twigs from different trees, such as elm, soft maple, box elder, oak, apple, cherry and others, a great dissimilarity will be noticed. This unlikeliness is due to various peculiarities, such as the character of the bark, the buds, and the development or suppression of branches. With very little study, it may be made clear that trees can be distinguished by their branches alone, without leaves, flowers, or fruit. The study of the tree in its winter aspect is of great interest.

44. **Bud arrangement.**—Taking a single twig, as the box elder, there may be seen peculiar crescent-shaped markings, uniting to form a ring, generally lighter in color than the rest of the twig, occurring at comparatively regular intervals, and becoming more distinct toward the tip. These are the *leaf scars,* and each marks the place of one of the last year's leaves. That part of the stem which

bears the leaf (two in this case, sometimes more or fewer) is called the *node* and the space between two successive nodes is the *internode*. The internodes become shorter toward the tip of the stem.

The *buds* are arranged one above each leaf scar, opposite each other and therefore in pairs up and down the stem. Each twig if uninjured terminates in a bud. This is the *terminal bud,* distinguished thus from all the others, which together are called *axillary buds.* This latter term results also from the position of the bud, each one being borne in the *axil* of a leaf, which is the angle inclosed between the upper side of a leaf and the stem upon which it is borne. This may be made clear by looking at twigs just before the fall of the leaves in autumn, and noting the position of the bud which has been formed during the summer's growth and which will remain upon the twig after the leaf has fallen.

If we look now at a twig from the elm, some differences may be noted. The leaf scars are present, and nodes and internodes may be distinguished as before, but here only one bud will be found at a node, and the ones at successive nodes will be on opposite sides of the stem. This is called the *alternate arrangement* of buds, while that of the box elder is known as the *opposite arrangement.*

Looking at twigs from many trees and shrubs it will be found that the greater number of them can be grouped under the one or other of these two classes of bud arrangement. The exceptions would be in the case of a few plants whose stems would bear more than *two* buds at a node, in which case the arrangement is said to be *whorled.* The catalpa is an example of this arrangement.

45. **Structure of a bud.**—For the study of the structure of a bud, the lilac offers good material. Taking a single bud and cutting it across, little pairs of undeveloped leaves and brown scales may be found packed away in it. With a needle point the brown scales may be picked away from the outer part, and they will be found to be hard, while the little green leaves inside are soft.

These may be picked away, until only a little green stem or core is left.

If buds that have been growing for some time may now be obtained, it will be seen that growth consists in the lengthening of this little core into a stem, upon which are borne the new leaves. The bud scales which covered these portions will have disappeared, or some of them may still be found in a cluster at the base of the new stem, their function as protecting envelopes ceasing when growth is well started.

46. **Kinds of buds.**—Sometimes the bud develops a stem and clusters of flowers instead of leaves, this is especially true of those buds which are borne near the tip of last year's growth. So buds may be of several kinds, considered from the standpoint of the structure which they develop: *leaf buds, flower buds,* or in many cases, *mixed buds,* giving rise to both flower and leaf.

Whatever structure develops from the bud, it is plain that it is simply an *undeveloped branchlet,* while a *branchlet* is *a developed bud.* This may be made somewhat clearer by a study of a soft maple twig of two or three years' growth. At some of the nodes there may be found short branchlets; they may supplant all the buds on the twig, or seem irregularly scattered, but in any case, close examination will show that where there occurs a branchlet there is no bud, but the branchlet occupies exactly the place in which a bud was to be expected.

The bud scales, it has been stated, are protective organs. These are essential for the bud in order to protect it from the extreme cold of winter and from the effect of sudden changes of temperature. In addition to these scales, buds often have a large amount of woolly and resinous substances for greater protection.

All of the buds above mentioned are *winter buds,* capable of living through the colder months of the year. In the herbs of temperate climates and even in trees and shrubs of tropical regions, the buds are often *naked,* that

is, nearly or quite destitute of scaly covering. This can be seen in the case of the bud of the common geranium.

Sometimes at a node of certain plants, there may be found extra buds; these are called accessory buds. Buds often occur in irregular places; that is, not terminal nor in or near the axils of the leaves. These are called *adventitious buds,* and may spring from the roots as in the silver leafed poplar, or from the sides of the trunk as in our American elm. In many trees, as maples and willows, they are sure to appear when the trees have been cut back.

All of the buds produced by a stem do not develop at the same time. Some may remain *dormant,* and this inactive condition may last for many seasons. Finally the bud may die, or some injury to the tree may destroy so many other buds as to leave the dormant ones an extra supply of food, and then they will develop.

47. **Vernation.**—The arrangement of leaves in the bud is called *vernation.* This arrangement varies greatly in different plants. Sometimes they are fan plaited, sometimes rolled, sometimes folded flat. The significance of this may be understood when we consider that two important purposes are to be served: (1) the leaves must be stowed away as closely as possible in the bud and (2) upon beginning to open they must be protected from too great heat and dryness until they have reached a certain stage of firmness.

QUESTIONS

1. What are some of the characteristics of Bryophytes? What plants are included in this group? How do Bryophytes compare with Thallophytes?

2. How many kinds of reproduction are exhibited by this group? What is alternation of generations?

3. What are liverworts? Where found?

4. What is marchantia polymorpha? Of what does the plant body consist? What are gemmae? Where found? What is their use?

5. Have you made a close study of the picture on page 20?

6. Describe the organs concerned in sexual reproduction. How is fertilization accomplished?

7. What is an oospore? Into what does it develop? What are elaters? What is their use?

8. How is alternation of generations illustrated in the liverwort? What is the advantage of alternation of generations?

9. What are mosses? Describe the process of vegetative reproduction. What is peat?

10. What is the protonema? Where do the moss plants originate? Where are the archegonia and antheridia produced? What is the process of fertilization? Describe the sporangium.

11. Do you see clearly the rhizoids, the buds, and the leafy branches, of the older protonema in the picture on page 23?

12. What classes of plants are included in the group of Pteridophytes? What is the most important characteristic of Pteridophytes?

13. Where are the spores of the fern produced? To what does a fern spore give rise on germination? Where are the antheridia and archegonia of the fern? To what does the oospore give rise?

14. Does the picture on page 25 showing the antheridia and the archegonia help you to understand how the oospore is formed?

15. What is the leafy portion of the fern called? What is a sorus? Of what is it composed?

16. Have you studied carefully the picture on page 27?

17. State two facts characteristic of the ferns.

18. Why are Spermatophytes often studied alone as botany? Why are they called seed plants? Of which generation is the plant body of a Spermatophyte?

19. To what points is the great dissimilarity of twigs due? What is a leaf scar? What is the node of a stem? The internode? Are the internodes all of the same length?

20. What is a terminal bud? An axillary bud? Why is each so called? What is the alternate arrangement of buds? The opposite arrangement? The whorled arrangement?

21. What is the structure of a bud? What are the kinds of buds? What is a bud? What is a branch?

22. Of what use are the bud scales? What else do buds have for this same purpose? What are naked buds?

23. What are accessory buds? Dormant buds?

24. What is vernation? What is its significance?

25. Where is the stem of the fern? Does it live more than one year? Under what conditions do ferns grow best?

26. Have ferns been more successful in former times than at present?

LESSON III

STEMS

48. **Use of the stem.**—To prepare its food, a plant must have certain raw materials which it takes into its system by means of roots and leaves. These raw materials are taken from the air, the earth, and the water. The *stem* is that organ of the plant which serves to bring the roots and leaves into communication with each other. Through its tissues the various food materials and fluids are distributed to the growing and working parts. The stem also serves an important purpose in holding up the buds, flowers, leaves, and fruit to the light and air.

49. **Classes of stems.**—According to structure, stems may be all grouped in two classes. One class may be represented by the shoots of the elder. This has a large amount of woody tissue, having a definite arrangement. The other class may be represented by the corn stalk, and in this there is a smaller amount of woody tissue, which is scattered irregularly through the stem.

Plants belonging to the elder type are called *dicotyledons.* Those belonging to the corn stalk type are called *monocotyledons.* The significance of these names will appear later.

50. **Monocotyledons.**—In a cross section of the stem of the corn, made between the nodes, there will be seen to be two kinds of material: (1) the predominant portion, or *pith,* and (2) the *wood*, represented by numerous fibers scattered through the pith, more numerous toward the outside.

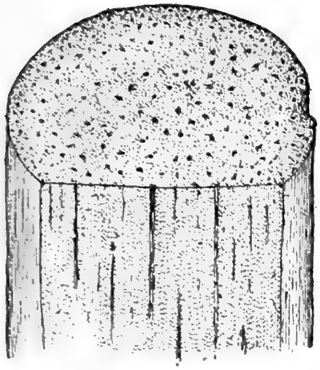

FIG. 214. Section of stem of corn, showing the scattered bundles, indicated by black dots in cross-section, and by lines in longitudinal section. —From "Plant Relations."

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The cells of the pith are so large that they may be distinguished with the aid of a hand lens. They are very thin-walled and all very much alike. They build up a very light vegetable tissue. Such a tissue is called *parenchyma*. It is the tissue of piths and the soft parts of plants generally.

51. **Fibro-vascular bundles.**—Dissecting out one of the fibers it will be seen to be of great length and also to possess considerable strength. If the end has been cut smoothly, the lens will disclose about four large openings. These are the ends of the tubes or vessels as they are called, whence the fiber is called *vascular*. The fibers make up the fibro-vascular system of the plant, and each is called a *fibro-vascular bundle*.

These fibro-vascular bundles in all stems form a conducting medium through which the water and dissolved foods move. In the case of the woody stems they are packed so closely that their vascular nature is not made visible except through microscopic study of the tissue.

52. **Mechanical function of bundle arrangement.**—The arrangement of the bundles in monocotyledonous stems has an important mechanical function. Looking at the cross section of a cornstalk, the bundles near the outside will be seen to be smaller, but are more and more packed together. In other monocotyledonous stems, as in the grasses, the bundles are arranged in the form of a hollow cylinder.

This gives very light, but at the same time, strong stems. It is well known that an iron or steel tube of moderate thickness has much more strength than a solid rod of the same weight per foot. The cornstalk is a solid cylinder, but is filled with very light pith.

These stems also have a flinty, outer layer of the stock, which adds to the stiffness of the stem.

53. **Dicotyledons.**—Take a shoot of the elder, and cut it squarely and smoothly off, preferably in the thinner portion. Dampen the cut surface a little to bring out the structure. It may be seen that the stem consists of three parts: (1) the outer called the bark or *cortex*, (2) the *woody portion*, and (3) the central portion or *pith*, sometimes called the *medulla*. Each of these portions is circular in outline, and in all woody stems each occupies always the same relation as regards position.

54. **The bark.**—With care the bark of the elder twig may be found to consist of three layers, the outer or *corky* layer, the middle or *green bark*, and the inner or *fibrous layer*. This primitive arrangement persists usually but a short time, in some cases, however, much longer than in others. If the layers are to endure they must be renewed from within, and the inner growth usually results in the pushing off of the outer layers. In most trees the inner bark finally contains masses of thick walled cells, much hardened, and is the only part of the bark that contains any living cells. The outer bark layers split up and disappear, or sometimes may cling for years, as in the case of the cork oak, the outer bark of this tree forming the cork of commerce.

The way in which this old bark falls off from different trees furnishes an interesting topic for study. Sometimes it falls in flakes of various sizes and shapes, as in the case of many of our common trees. In the birch it peels off in bands or sheets around the stem, in the grapevine it peels in long strings, and in the case of the apple, it strips around the stem.

The roughening and cracking of the inner bark which remains on the stem is due in large measure to the effect of the weather.

In the outer bark of young twigs, and on the bark of rather old stems, in the case of some trees, are to be found openings called *lenticels*. These first appear as roundish

spots of small size, but as the twig on which they appear increases in diameter, the lenticel spreads at right angles and sometimes forms rather large transverse scars or slits, as in the cherry. The purpose of the openings is to admit air to the interior of the stem.

55. **The wood.**—The first thing of importance in regard to the wood is to remember that it is composed of fibro-vascular bundles, just as in the case of the cornstalk, but that here we have the other type of arrangement of the bundles, and that is, in the form of a *ring* which takes up by far the greater portion of the older stems. In many of the older stems the pith has nearly disappeared, but in shoots of a single year's growth, the wood, pith, and bark form rings all of about the same thickness. So with age the woody portion increases, and the others decrease in proportionate amount.

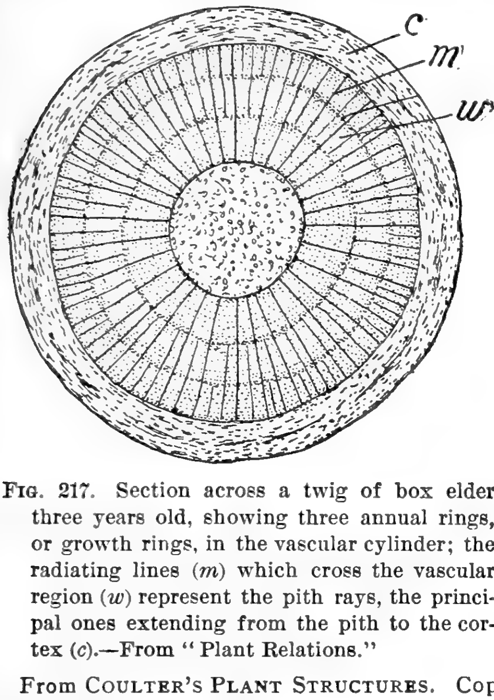

FIG. 217. Section across a twig of box elder three years old, showing three annual rings, or growth rings, in the vascular cylinder; the radiating lines (*m*) which cross the vascular region (*w*) represent the pith rays, the principal ones extending from the pith to the cortex (*c*).—From "Plant Relations."

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In both older and younger woody stems, the bundles are separated at quite uniform intervals by lines radiating from the central pith. These lines are parts of the pith which extend between the bundles, and are called *medullary rays,* parts of the medulla.

As the fibro-vascular bundles increase, these rays must of necessity become smaller on account of the lessening space, and so in stems of medium age are represented only by thin plates. The cells of these rays are of use in holding the food which the plant in temperate and cold cli-

mates stores up in summer and fall for use the following spring. In the very young plant these rays also serve as channels for the transference of fluids from stem to bark and the reverse.

These cells, it is said, are among the longest lived of all plant cells, often retaining their vitality for more than a century. This is perhaps due to their importance.

56. **The cambium.**—In thin cross sections of young woody stems, there may be seen by the aid of the microscope, a layer of very delicate cells, like those of the pith, but much smaller, and even more thin-walled. This layer is between the wood and the bark. It is called the *cambium layer,* and is the growing portion of the stem, that is, it is the only portion that has power to develop new cells and thus cause it to *grow.*

In the growing season, these cambium cells do three things: (1) they increase their own number, (2) some of them on the outside produce new bark cells, thus forming a new layer on the inside of the bark, (3) some next the wood become changed into wood cells, and so add a new layer to the wood.

The presence of the cambium in the stem is illustrated in the early spring, when this layer is apparently most active, and it is so gorged with rich, nutritive material, that the bark seems to be loose from the wood. The sweet taste of this pulpy layer as found in the slippery elm and other stems, is a familiar evidence of the nourishment contained in it.

57. **Increase in diameter.**—The amount added to the stem in a year by the aid of this cambium layer can be determined to some extent. In temperate climates, where there is an annual growing and resting period for plants, the cells formed by the cambium in the spring are larger and more distinct; those formed in the fall are less so, and so there is usually a distinct line caused by the difference in the character of the cells at the different times. The concentric rings thus formed will give us by counting them, an idea of the age of the tree. It will not give the

exact age, for sometimes there is more than one growth period in a year. Over twelve hundred layers have been counted in the stumps of some of the giant redwoods of California, and there are trees now living that are probably much older.

58. **Knots.**—Sometimes the annual rings in trees are interrupted by knots. These are formed by fibro-vascular bundles which have been connected with buds on the stem. As the bud grows the fibro-vascular bundles increase in number and form a cylinder of wood, at an angle with the annual rings. If the branch dies before the growth of the stem stops, the knot will be buried under the new layer of wood. Lumber free from knots is obtained from trees which have grown in a dense forest, where the lower branches through inability to obtain light have died long before the tree was felled.

59. **Growth of stems.**—It has been seen in the study of the dicotyledonous stem, that growth takes place through the agency of the cambium layer, and consists of successive additions to the outer part of the stem. Hence the stem increases in diameter and is also increasing in length.

For the most part, monocotyledonous stems do not increase in diameter, but only in length. There is no cambium layer in the stem, by which such growth might be accomplished. Where such stems do increase in size it is only through the increase of the individual tissue elements, but they do not increase the number of the bundles.

The old terms for the two classes of stems, *exogens* (outside growers) and *endogens* (inside growers), are no longer generally used. They were so called because of the mistaken belief that the monocotyledonous stem increased in diameter by the growth or addition of new bundles inside the stem.

The terms monocotyledons and dicotyledons arise from the number of primary seed leaves found in the seeds of the two different types of plants. The seed leaves are called *cotyledons.* The seeds of all plants having the wood arranged in circles around the pith, have two cotyledons,

hence these plants are *di*cotyledons. The only exception to this is the conifers (trees of the evergreen types), which have *more* than two cotyledons in the seed. Those plants having the bundles irregularly scattered in the stem have but one cotyledon in the seed, hence are *mono*cotyledons.

60. **Work of the stem.**—The function of the stem as a conductor of material to and from parts of the plant has been suggested. This material which it conducts is commonly called *sap* and consists of water with various substances dissolved in it. This sap is not the same substance in all parts of the plant, but differs according to the part of the plant in which it is found. Sometimes it is nearly pure water, and at other times it contains great stores of food.

61. **Upward path of sap.**—If some branches newly cut from an apple tree are allowed to stand for several hours with the lower end in red ink, and then are examined in successive portions of the stem, it will be seen that the ink has ascended through the newer layers of the wood. As forest trees will live after the heartwood has decayed, and some will live after the bark has been removed in a ring extending around the trunk, it may be concluded that sap containing food materials in a crude form ascends through the newer wood to the leaves. In the leaves it is made into the elaborated forms.

62. **Downward path of sap.**—If a willow shoot is girdled by removing a strip of the bark and then placed in water, after a few weeks that portion of the twig above the girdle will send out roots abundantly, while but few, if any, will be sent out from the portion below the girdle. In all the region above the girdled ring there is evidently an extra amount of food, while the lower contains but little. This would tend to prove that the bark conducts elaborated sap downward through the stem, for the girdled portion here prevents the food from passing into the lower part of the stem.

63. **Movement of water in the stem.**—How the movement of water in the stem is accomplished is not def-

initely known, though many theories are advanced to explain the phenomenon. It is not, as has so often been stated, a circulation similar to the circulation in animals, for the tubes through which the movement takes place are not continuous and open like those of animal bodies, but are sets of closed vessels communicating with each other in various ways.

If a section is made of a stem with its attached leaf, the bundle will be seen to run out into the leaf, and so it is evident that there is a continuous route for the passage of water from the root to the leaves.

64. **Duration of stems.**—A rapid survey of a large number of the stems of common plants in regard to their duration, will serve to classify them. They may be placed in two classes: (1) those which die completely on the approach of winter, as the tomato, or die down to the ground, as the asparagus, and (2) others that persist, retaining their stems from year to year. Stems which die before frost are called *herbaceous;* persistent stems, by way of contrast solely, are called *woody.* All the woody-stemmed plants of northern latitudes, except one or two, are dicotyledons. It is only in the tropical regions that monocotyledons exhibit persistent stems.

In the case of the persistent dicotyledonous stem, it is only the outer portion of the stem which lives. The inner part of the stem, called the *heartwood,* and often distinguishable from the rest of the stem by a difference in color, is no longer living. This is demonstrated by the fact that the water current has abandoned it, and also by the fact that hollow trees live and flourish as well as those that are solid.

The outer part of the stem called the *sapwood* is the part which, in general, contains living tissue, and through which the water current still passes.

65. **Habits of stems.**—As regards their habit of growth, stems may be divided into several classes. They may be *erect,* as in the case of most of our familiar plants, or they be *climbing, prostrate,* or *repent.*

Climbing plants have various devices by which they make their way up to light and air. In the morning glory the ascent is made by twining the stem around a support. The grape climbs by means of *tendrils,* organs developed for the purpose of holding the plant fast to a support. The Virginia creeper illustrates two methods of climbing. One is by means of little rootlets which grow into the wall or tree trunk which forms the support, the other is by means of a specially adapted tendril. These have little discs or suckers at their tip, by means of which the plant may obtain a firm footing on a comparatively smooth wall.

Prostrate stems are illustrated by the pumpkin and melon vines, whose whole length lies on the ground even though the tip does show a tendency to rise.

Repent stems are the creeping stems. They also are prostrate but attach themselves at intervals to the soil by bunches of roots. The clover and strawberry are good examples of this type.

66. **Special forms of stems.**—The function of the stem in general has been suggested, but there are some special forms of stems to be considered which have a different and additional function. In those plants which die down to the ground on the approach of winter, there must be a storage of food either in the roots or in some portion of the stem which is underground.

So some plants have developed certain subterranean stems which are known as *bulbs, tubers* and *rootstocks.* The onion and the lily furnish examples of bulbs, while the underground portions of Solomon's seal, the raspberry, and ferns, give us examples of rootstocks. The most common of all tubers is the potato.

67. **The potato a stem.**—A study of the potato will develop the fact that it is a greatly modified stem. If a potato is cut into portions each containing an *eye,* and these portions are then planted, new plants will develop from each piece. This is because the eyes are really buds, or undeveloped branches. The arrangement of the buds

can easily be made out. A little scale is placed at the lower edge of each eye, and this is a rudimentary leaf.

Splitting a potato lengthwise the three parts of the stem may be distinguished: (1) the pith very large, (2) the wood, a faint brown line around each section, and (3) the bark rather thick. Outside of this is a thin skin, the epidermis.

Chemical tests will prove that the mass of this potato is made up very largely of starch, which is a form of food well adapted for storage purposes. That this is a store of food for the plant's use is shown by the fact that when the potato has been sprouting for some time, it is known that there has been a loss of material from the tuber.

68. **Uses of tubers and bulbs.**—In countries having a wet and a dry season, tubers and bulbs carry the plants through the dry season. When the rainy season returns, the plants develop and bloom very rapidly, causing a marvelous transformation in the landscapes of such countries, in a very short time.

QUESTIONS

1. What is a stem? What functions does it have?

2. How many classes of stem structure? What are dicotyledons? Monocotyledons? What are the type plants of these groups?

3. What are the parts of the stem of the corn? How arranged? What is a fibro-vascular bundle? What part of all stems is formed by these bundles?

4. Have you examined with a lens a cross section of a corn stalk? Does the picture on page 35 fairly represent what you observed?

5. What is the mechanical function of the arrangement of the bundles in the stem of the corn?

6. What are the parts of a stem of the elder? What is the shape of each part? What is the relation of the parts?

7. Of how many layers does the bark consist? What part of the bark is living? What becomes of the old bark? What is cork?

8. How does the old bark fall from different plants? To what is the roughening of the bark due? What are lenticels? What is their purpose?

9. Of what is the wood composed? What is the relative size of pith, wood, and bark, in old and young stems? What are medullary rays? What is their importance?

10. By inspecting a cross section of a large twig, have you verified the facts shown in the picture on page 37?

11. Where is the cambium layer? What is it? What can it do? How is the formation of annual rings in the wood of trees explained? How are knots formed?

12. Compare the growth of the dicotyledonous and monocotyledonous stem.

13. From what do the terms dicotyledons and monocotyledons arise?

14. What is the function of the stem? What is sap? Is sap always the same? Why not?

15. Through what part of the stem does the sap ascend? How is this proven? In what form is it when ascending? When descending?

16. What part of the stem conducts the elaborated sap? How is this proven? How does the circulation of sap through the stem compare with animal circulation?

17. What is an herbaceous stem? A woody stem? How much of a woody stem is living tissue? What is heartwood? Sapwood?

18. How are stems classed according to habits of growth? How do climbing plants make their way up to light and air? What are prostrate stems? Repent stems? Erect stems?

19. What additional function may some stems have? What is a subterranean stem? What is a bulb? A tuber? A rootstock?

20. Why is the potato to be classed with stems? How is it evident that the potato is a form of stem for food storage? Of what use are these subterranean stems to plants?

LESSON IV

ROOTS AND LEAVES

69. **Variation in roots.**—Roots in their development do not show as much variation as the other organs of the plant. This is due to the uniformity of conditions to which they are exposed in the ground. Aerial roots, belonging to plants which live wholly in the air, usually show more of a tendency to modification than do the soil roots. Whatever the type of the root may be, it is serving the function of either an absorbent organ or a holdfast and often performs both functions.

We know that the general direction of roots is downward, but what efforts the plant will make to keep this direction is not always known. If seeds of various plants are put in the ground and wrong side up the root will turn as it grows and take its appropriate direction. For this reason the root is sometimes called the descending axis and the stem the ascending axis of the plant.

70. **Kinds of roots.**—The first root that starts out from the seed is called the *primary root.* Other roots of the plant which succeed it in development are called *secondary roots.* In some plants the primary root continues to develop until it has become larger and stronger than the rest of the roots. This is called the *tap root.* The dandelion possesses a well developed tap root, as do many other weeds and also many trees.

In some cases the primary root instead of soon sending out secondary roots, grows thick and fleshy, as in the beet and the carrot, and this *fleshy root* has an additional function, the storage of food for the purposes of carrying the

plant over a period of enforced rest. Those roots which do not develop the fleshy form but retain the thread-like forms which they first develop, are called *fibrous roots.*

Roots are different from stems in that they do not bear buds or leaves. It is true that a few fleshy roots do bear buds, but in this case they are adventitious. The sweet potato is a root, but it bears this type of buds, and these give rise to the new plants.

71. **Structure of roots.**—Though composed of essentially the same elements that are to be found in the stem, the relation of these parts to one another in the root changes in some respects, and there are some additional structures.

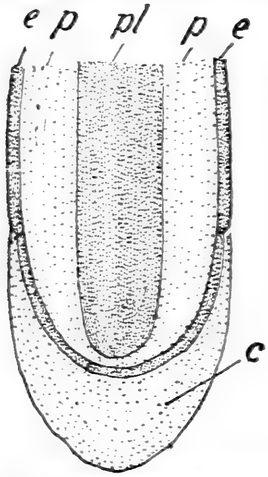


FIG. 275. A longitudinal section through the root-tip of shepherd's purse, showing the plerome (*pl*), surrounded by the periblem (*p*), outside of periblem the epidermis (*e*) which disappears in the older parts of the root, and the prominent root-cap (*c*). —From "Plant Relations."

By the aid of the microscope, the structure of a young root of any common plant may be shown. Upon the tip of the root will be seen a cone-like structure of cells. This is for the protection of the tip of the root, as it pushes its way through the soil, and is called the *root cap.*

The woody portion of a root is in the form of a cylinder, forming a tough and fibrous central axis, and around this is a wide region of spongy structure, which is the cortical portion.

These young roots are also provided with *root hairs.* These are delicate tube-like structures which are outgrowths from the epidermis of the root, and are found most abundantly a short distance above the tip of the root, which is the growing portion. These root hairs are the absorbing organs of the plant. They are so small that they are able

to penetrate the crevices of the soil and take up from it all the moisture and dissolved food needed by the plant. Their great number upon the many divisions of the root gives to the plant a very large amount of absorbing surface.

These hairs are so small as to be invisible in many cases, but on some plants are so large that they show plainly. This is true of the clover and the corn. These plants, however, if pulled from the earth will not show the root hairs, for they are broken off in the process. But if the seeds of these plants are developed at the surface of a glass of water, the root hairs can readily be seen.

The delicacy of the root hairs will explain why plants often do not grow when transplanted. It is plain that root hairs are very necessary structures, and in the unavoidable handling they are broken off. The plant having nothing by which to obtain food and moisture in its new situation, is unable to develop new root hairs and so dies. Trees that are transplanted in the winter time are usually the most successful in their new situations, because the frozen ground forms a ball around the roots and prevents the destruction of the root hairs.

The root hair is *not* a *young root.* It has a very short duration of life. But as rapidly as the hairs die, new ones are found to take their places on the portion of the root where they are most needed.

72. **Absorption of water.**—In order to understand how it is possible for plants to receive water from the soil, a physical process known as *osmosis* must be understood.

A theory in physics states that the molecules of fluids are in constant, imperceptible movement. This movement may be made perceptible if we take a salt solution and put it in a jar which can have the opening closed by a membrane, as a sheet of parchment, and place it in a jar of water. Here we will have the salt solution on one side of the membrane and pure water on the other. After a time the salt solution will be seen to have absorbed some of the water through the membrane, and increased its own volume.

Soil water passes through the walls of the root hairs and mingles with the liquid contents of the cell by this same process. This soil water, which is practically identical with spring water, is separated from the more or less sugary or mucilaginous sap inside of the root hairs, only by their delicate cell walls, which are lined with a layer of protoplasm. The soil water will pass very rapidly into the plant through these walls, but very little if any sap will come out, and this water will be carried from cell to cell throughout the plant by this same osmotic action.

73. **Selective power of protoplasm.**—The activity of protoplasm is very well illustrated by this absorptive power which it exhibits in the cells of the root hairs. Plants of different species growing in the same soil usually take from it varying amounts of mineral matters. Some will take more lime than others, and some more silica and so on. This difference is due undoubtedly to the selective action (see page 4) of the protoplasm in the absorbing cells of the roots. It acts here as though endowed by intelligence, not simply permitting the food materials to pass through, but letting in some and letting out others, keeping in some and keeping out others.

74. **Soil water.**—The water which is valuable to the plant is not free water, but is in the form of a thin film of moisture around each tiny particle of the soil, and adheres to the particle. So the finer the soil is the greater the number of particles, and the consequent larger amount of film moisture which is placed ready for the plant's absorption. So the fineness of the soil is an essential thing in the growth of plants, not only that the root hairs may more easily penetrate it, but also that the amount of water which the plant can use may be increased. Root absorption may be carried on thus in a soil that to us seems to be mere dust.

75. **Extent of root systems.**—It is difficult to determine the total length of the roots of ordinary plants, because of the fact that when we take a plant up from the earth a large part of the roots must be broken off and left

behind. But some studies of plants have been made in regard to this point, and it has been found that the length of the roots is much greater than is ordinarily supposed. The roots of winter wheat have been found to extend to a depth of seven feet.

In soils where the water supply is poor, the root systems will often be enormously developed, as they will extend in all directions and go long distances for water. It is said that the Mexican farmers follow the roots of the mesquite bush as guides when digging wells, and they have been found to extend to a depth of seventy feet and more.

76. **Duration of roots.**—According to the length of time the root will live, plants are classed as annuals, biennials, and perennials. An *annual* is a plant in which death of the whole plant system occurs at the end of the season. A *biennial* plant endures for two seasons, and when a plant endures for three or more seasons it is said to be *perennial.*

In the last two classes it is evident that there must be a storage of food to carry the plant over the winter periods. How it is done with the biennials is illustrated in the case of the fleshy roots, and the roots of perennials, though not fleshy roots, also contain a large amount of stored plant foods. In the case of some perennials, as the rhubarb, the plants die down to the ground in the fall, and make a rapid growth in the spring from the materials stored up in the roots.

LEAVES

The higher plants have the leaves developed as special organs to do certain parts of the work of nutrition. This work is carried on by the green parts of other plants which do not bear leaves, but the leaf as a separate organ can do it better.

77. **Duration of leaves.**—A study of a maple twig and one from the pine, taken during the winter, will show that leaves are of two kinds, those which fall on the approach of frost and are termed *deciduous,* and those

which remain on the stem from season to season and are termed *persistent*.

The leaves of the *evergreen* are persistent only for a number of years, two or three, or they may last for ten or twelve years. That they do not persist for longer periods of time may be shown by the fact that all the branches of older growth are not covered with them, but that from the older portions of the leaves have fallen, leaving the branches roughened by numerous leaf scars.

In the tropics many trees retain most of their leaves the year round, dropping a leaf occasionally, but no great number of them at any one time. So there, most trees are evergreens, just as the pines and their allies are evergreen in our northern latitudes.

78. **Fall of the leaf.**—The leaf during the latter part of the season is preparing for its separation from the stem. A layer of cells is formed between the stem and the leaf by the division of all the living cells in the plane of separation. At a later stage, a layer of cells in the middle of this layer is absorbed, and the leaf becomes divided from the stem. The wound on the stem either simply dries up, as in the case of the fern, or is closed by a layer of cork, forming a leaf scar.

So it is seen that the fall of the leaf is not due to the action of frost, but is only hastened by it. The leaf dies and would fall at a later stage if the frost did not intervene to bring about its earlier separation from the stem.

79. **Arrangement of leaves.**—A study of some twigs of the oak and maple will show that leaves have the same arrangement as buds. On the oak there is but one leaf at a node, so the arrangement is *alternate*. On the maple the leaves are placed two at a node on opposite sides of the stem and are *opposite*. On the catalpa three leaves are found at a node, forming a circle and hence are said to be *whorled*.

80. **Parts of a leaf.**—The leaf of the common geranium furnishes good material for study. It will be seen to consist of three parts: (1) the long slender stalk or

petiole, (2) the thin expanded portion of the leaf, the *blade,* and (3) at the base of the petiole are attached a pair of green, leaf-like appendages, the *stipules.* A leaf exhibiting all these parts is said to be a *model* or *typical* leaf.

Leaves may consist only of blades and petiole, lacking stipules, or they may also lack the petiole, thus consisting only of the blade. In the latter case they are said to be *sessile.* The stipules are not always leaf-like, but may be spines or prickles as in the locust, or tendrils as in the smilax or greenbrier. The structure and functions of leaves, together with the kinds of leaves, will be discussed in the next lesson.

QUESTIONS

1. Why do not roots vary as much as the other organs of the plant?
2. What are aerial roots? Why do they tend to vary more than soil roots?
3. What are the two main functions of roots?
4. Why is the root called the descending axis of the plant? What is a primary root? A secondary root?
5. What is a tap root? What is a fleshy root? A fibrous root?
6. Do roots bear buds? What is a root cap? Its purpose?
7. After studying the illustration on page 46, do you understand the construction and use of a root cap?
8. Where is the woody portion of the root? Has a root bark?
9. What are root hairs? Where found? Of what value are they to the plant? Why are they so numerous?
10. Why do plants often not grow when transplanted? Why is it better to transplant trees in the winter time?
11. What is osmosis? How does water pass into the cells of the root hairs? How do these root hairs illustrate the activity of protoplasm?

12. In what form is the soil water which is valuable to the plant? Why is it well to keep the earth about a plant in a finely divided condition?

13. What can be said of the extent of root systems? In what regions are the root systems often best developed? Why?

14. What are annuals? Biennials? Perennials? When and how does the root act as a storage organ?

15. What is the general function of leaves? Is this work carried on by the leaves solely?

16. What are deciduous leaves? Persistent leaves? For how long a period do persistent leaves remain on the stem?

17. How does a leaf fall in the autumn? Is the frost responsible for its fall?

18. What are alternate leaves? Opposite leaves? Whorled leaves?

19. What are the parts of a leaf? What is a typical leaf? What is a sessile leaf? Are stipules always leaf-like?

LESSON V

LEAVES, CONTINUED

81. **Structure of leaves.**—The leaf of the white lily offers good material for the study of the structure of a typical green leaf. With a knife blade there may be stripped from the outer surface a thin layer. This is a transparent membrane, the *epidermis.* If this epidermis is now placed under the microscope, its cellular structure can be seen very distinctly. At intervals where two cells meet may be seen an opening which is guarded by two thin-walled cells. These are the *breathing pores* or stomata (singular stoma) by means of which direct communication is established between the external air and that inside the leaf.

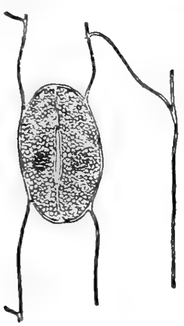


FIG. 29. A single stoma from the epidermis of a lily leaf, showing the two guard-cells full of chlorophyll, and the small slit-like opening between.

The cells around the opening, or *guardian cells* of the stomata as they are called, are soft and delicate, and have the power of regulating the size of the opening between them. They may straighten out so that the slit is closed, or become more convex so that the slit is more widely opened. These openings are small but very numerous. The total number upon an average leaf is very large. A space equal to the area of an ordinary pinhead may have as many as 2,000 stomata in it.

The advantage of the small size of the stomata is that they are not readily clogged by water upon the surface of the leaf. Many leaves also have wax or *bloom* upon their upper surfaces to aid the water in rolling off and thus keep the

stomata clear. If the stomata were to become filled with water their activities would cease until they were freed from it.

Hairs of various sorts are also present on the leaf surface to keep dust from clogging up the stomata. Many leaves have stomata on the under surface solely. This is especially true of leaves having a horizontal position. With vertical leaves there is an equal distribution of stomata on both surfaces.

If a cross section of a leaf be examined under the microscope the epidermal cells will show very plainly, as clear,

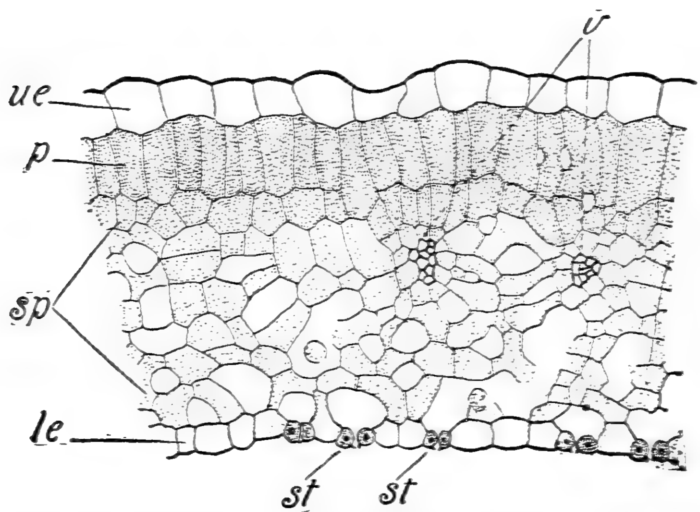


FIG. 278. A section through the leaf of lily, showing upper epidermis (*ue*), lower epidermis (*le*) with its stomata (*st*), mesophyll (dotted cells) composed of the palisade region (*p*) and the spongy region (*sp*) with air spaces among the cells, and two veins (*v*) cut across.—From "Plant Relations."

colorless cells. Just beneath the upper layers will be found a layer of cells, closely connected with each other. These are the palisade cells and contain the greater part of the green coloring matter of the leaf, the chlorophyll. Underneath the palisade cells are other rather spongy cells of different shape, and these are arranged in groups leaving large *intercellular spaces*. These spaces can be traced through the section and the fact that they connect

directly with the stomata on the under surface will be made very clear.

82. **Function of each part.**—The function of the leaf will appear a little later, but the particular function of each part may be stated briefly here. The epidermis prevents excessive evaporation, strengthens the parts beneath and prevents injuries to them. The palisade cells hold the green matter in such a way that it can receive enough, but not too much, sunlight, and the cells of the spongy part share the work of the palisade cells and also evaporate much water. The stomata admit air to the interior of the leaf, to the intercellular spaces. They permit oxygen and carbonic acid gas to escape, and they also regulate the evaporation of the water. The health of the plant is due in a large measure to the stomata. One reason why plants in large cities often fail to thrive is because the stomata become choked with soot and dust.

83. **Venation.**—One other fact is to be noted in regard to the structure of the leaf. The soft parts are held in an expanded form by a network of woody fibers. These are the fibro-vascular bundles which are continued into the leaf from the stem, and serve to conduct the food materials into the leaf and to keep it in the expanded form. These bundles we call the veins, and their arrangement in the leaf constitutes the *venation.* The largest veins, which are the branches of the petiole, are called *ribs.* The different kinds of venation may be illustrated by leaves from the elm, geranium, narcissus or amaryllis, and canna.

The elm leaf will show a prominent central vein, with secondary veins running obliquely from it, like the barbs of a feather, hence the leaf is *pinnately veined* or *feather-veined.* Small veinlets form a network between the secondary veins, hence the elm is *netted-veined,* and being pinnate, is said to be *pinnately netted-veined.*

In the geranium the large veins diverge from the end of the petiole like the fingers from the palm of the hand,

and the leaf is thus *palmately veined.* It also has netted veining and is *palmately netted-veined.*

The amaryllis shows a very prominent central rib, with numerous smaller veins, which extend from the base of the leaf to the apex, and no smaller veinlets forming a network can be distinguished. These veins then are

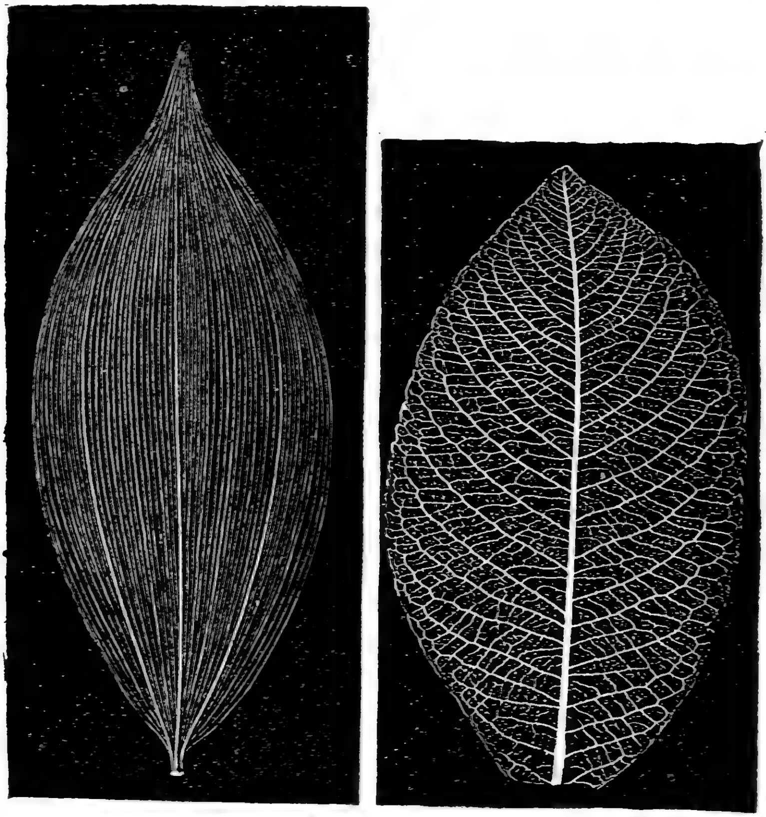


FIG. 215. Two types of leaf venation: the figure to the left is from Solomon's seal, a Monocotyledon, and shows the principal veins parallel, the very minute cross veinlets being invisible to the naked eye; that to the right is from a willow, a Dicotyledon, and shows netted veins, the main central vein (midrib) sending out a series of parallel branches, which are connected with one another by a network of veinlets.—After ETTINGSHAUSEN.

approximately parallel, and as they diverge from the base the leaf is *palmately parallel-veined.*

The canna has also a prominent central vein, but the secondary veins here are pinnate. The network between the veins cannot be distinguished and so the leaf is *pinnately parallel-veined.*

84. **The work of the leaf.**—The leaf and in fact all the green parts of the plant form the laboratory of the plant. Here the crude food materials are prepared for use. Some of these crude materials the leaf obtains by direct absorption from the air, and some are brought to it in solution in the water absorbed by the roots.

The work of the leaf can be carried on only in the light. Sunlight is the best light, but plants have been found to grow well under the influence of strong electric light, This is because chlorophyll is the necessary agent in the work and chlorophyll forms only under the influence of light. This is demonstrated in the case of those plants which have been shut away from the light for some time, and have their leaves blanched in consequence.

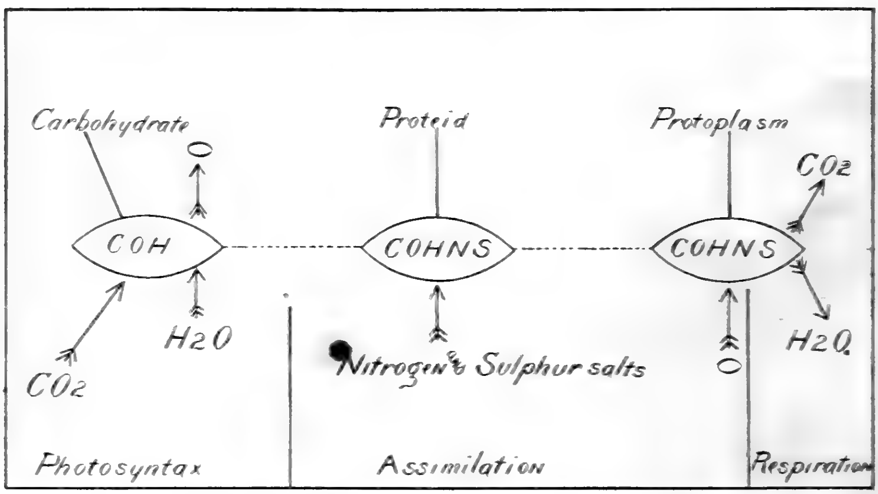
Some statements about the food of plants have already been made, but it is well to state clearly the fact that green plants are able to live without help from other organisms because they have the power of using inorganic material as food. They have the power of organizing this inorganic material, that is, making it into organic matter.

85. **Materials required.**—The materials required by the plant in carrying on this organization are carbon (C), hydrogen (H), oxygen (O) and nitrogen (N), and more or less of sulphur, potassium, calcium, phosphorus and other elements. The plant obtains these elements in the form of inorganic compounds. Carbon it obtains from the carbon dioxide (CO_2) of the air and oxygen and hydrogen from the water (H_2O) which it absorbs from the soil. The water holds in solution the various salts of nitrogen and other elements which are obtained from the soil. These substances can be used by the plant only when in the form of a gas or liquid, as they must pass through the cell wall.

86. **Photosyntax.**—After a plant has obtained these inorganic compounds, it has the power to break them up into their elements, C, O and H, and to unite these again into compounds called carbohydrates (starch, sugar, etc.). At the same time some oxygen is formed as a waste product, and is given off to the air. This part of the plant's work is termed photosynthesis or *photosyntax*, words which indicate that the presence of light is necessary. The mechanism for the work is the chlorophyll bodies, which when exposed to the light are able to do this work.

It is evident then that green plants must have a good leaf exposure, both for light and air, and that they cannot live if kept in darkness. And it is not only the leaves that carry on this work, but *all* the green parts of the plant are engaged in it.

87. **Digestion and assimilation.**—After the carbohydrates are formed they serve as a basis for the further work of the plant. Adding to the carbohydrates other elements, particularly nitrogen and sulphur, the plant



forms a class of very complex foods called *proteids*. These may be made in any part of the plant, they are not dependent upon light for their formation.

These two substances thus made must be transported to the regions where they are needed, and therefore must first be *digested,* or made into soluble form. If the substance is insoluble, as the starch made by the plant, it is turned into some soluble form, as sugar, and is then transported.

When the carbohydrates and proteids are finally transported to the places where they are to be used, they are then *assimilated;* that is, they are made into whatever the plant requires, either the enormously complex substance protoplasm, which is itself a proteid and which then builds the plant structure, or they are transported to storage portions and there reconverted into insoluble forms, as starch and the like.

88. **Respiration.**—In order to do all this work the plant must have energy and this is obtained in the same manner as the animal body obtains it, through *respiration.* (See page 3.) The plant absorbs oxygen from the air, combines it with its protoplasm, and thus the protoplasm is *oxidized.* This oxidation is similar to that process by which a piece of wood burns, the union of oxygen with the wood oxidizes it, and releases energy which may be applied to an engine to enable it to do work.

In the plant cell the union of oxygen with the protoplasm releases energy by means of which the plant is able to carry on its work. The protoplasm in undergoing this oxidation is torn down, that is, it is broken up into several chemical compounds, some of which are used again by the plant, while others as water and carbon dioxide are given off as waste products.

This absorption of oxygen and giving out of carbon dioxide goes on in all the organs day and night. When it ceases the death of the plant follows rapidly. If the plant cannot get oxygen from the air it may live for a short time upon that which is stored in the intercellular spaces, but this will suffice only for a few hours.

This process of respiration it will be noted is exactly the reverse of photosyntax. It does not depend upon the chlorophyll bodies, for it goes on in plants and parts of

plants which are not green. It goes on in every living part of the plant.

Once it was thought that plants differ from animals in the fact that plants absorb carbon dioxide and give off oxygen, while animals absorb oxygen and give off carbon dioxide. But it has since been found that no such difference exists, but that the process of respiration is identically the same in both. The difference lies in the fact that the green plants have the *added work* of photosyntax.

All these chemical changes concerned in the process of nutrition of the plant body are grouped under the general term *metabolism*. (See page 4.) This metabolism is of two kinds, (1) constructive, which includes those changes which build up complicated substances out of simple ones, and (2) destructive, which is the reverse of the former. (See diagram page 58.)

59. **Transpiration.**—A fourth function of the leaf of the plant is *transpiration*. In order to get the food materials to the leaves of the plant from the roots, more water is absorbed by the plant than it can make use of and this water is given off to the surrounding air through the stomata by the process of transpiration. This can be demonstrated by putting the petiole of a vigorous leaf through a perforated cardboard resting upon a tumbler containing water, and inverting another tumbler over the blade of the leaf. The moisture given off by the still vigorous leaf will be condensed on the inner surface of the tumbler. The amount of moisture given off by a single leaf in this experiment will give some idea of the vast amount of water given off by field of wheat, a field of corn, or a forest.

The amount of transpiration varies with the conditions to which the plant is subjected. If moisture is present in great quantities, transpiration will be more active, if in lessened quantities the process will be checked. The evaporation is regulated by means of the stomata, which are able through their guard cells to open and close as occasion requires. Plants in desert conditions would naturally

have but few stomata on small evaporating surfaces, as compared with plants in conditions where water was abundant. These would have many more stomata and greater leaf expanse.

The fact of importance in connection with transpiration is not the mere giving off of the water, but the fact that this escaping water is an external indication of work going on within the leaf.

90. **Kinds of leaves.**—Leaves are of two kinds, *simple* and *compound.* The simple leaves have the blade all in one more or less continuous piece, while the com-

FIG. 218. Leaves showing pinnate and palmate branching; the one to the left is from sumach, that to the right from buckeye.—CALDWELL.

pound leaves have the blades divided into separate divisions, or *leaflets.* Most of the leaflets have distinct stalks, which are more or less distinctly joined to the midrib.

This last character, together with the complete division of the blade into leaflets, characterizes compound leaves, and constitutes the main difference between the *divided leaves* and nearly all compound leaves.

In compound leaves there is to be noted a variation in the number of leaflets, and also in the manner of division, the leaflets in some being arranged in the pinnate order, such leaves being *pinnately compound,* and in the others *palmately compound.*

The leaves of the cherry, violet, oak, maple, and geranium, are illustrations of simple leaves. The leaves of the rose and honey locust are examples of pinnately compound leaves, while the leaves of the clover, sweet buckeye, and rue anemone are illustrations of the palmately compound leaf.

91. **Special forms of leaves.**—Leaves do not always do chlorophyll work solely, and to serve other functions they sometimes take special forms.

(1) *Bud scales.*—Of bud scales we have already spoken, and that these are leaves can be shown in many plants. When they first begin to send out new shoots, a gradual transition from the outer brown bud scales to the green leaves may be seen.

(2) *Tendrils.*—For the purpose of carrying its organs up to the light and the air, the plant develops a climbing habit and is held and supported by tendrils. These tendrils are modifications of the leaf, sometimes of the whole leaf, and sometimes of a single leaflet of a compound leaf, as in the case of the sweet pea.

(3) *Spines.*—On some plants spines are found which the plant has developed to protect it from destruction by browsing animals. In the axils of these spines buds are borne, and this shows that the spines are really leaves. On some shoots of the barberry, spines may be found which show a gradual transition from the true leaf to the spine.

(4) *Scale leaves.*—The scales or coats of the onion are leaves, or the fleshy bases of leaves. Removing the outer coats, the inner ones will be seen to bear more or less per-

fect leaves at their tips. Subterranean stems, as rootstocks and tubers bear leaves in the form of minute scales. All these are known to be leaves, because buds can be found in their axils, just as in the case of the well developed leaves of the plant.

(5) *Flytraps and pitcher plants.*—Two remarkable plants, the Venus's flytrap and the sundew, have leaves peculiarly modified for the purpose of entrapping insects. The leaves of the sundew are round, covered with a sweet, sticky substance which attracts the insect, and are surrounded by a circle of tentacles or hairs. When an insect alights upon the hairs, it becomes fast in the sticky substance secreted by them, and they gradually bend inward and press the insect down upon the leaf. Then the leaf pours out a digestive fluid and digests and absorbs all the soft portions of the insect's body. The Venus's flytrap has its leaf blade constructed upon the plan of a steel trap. Over its surface are some sensitive hairs and when the insect touches these, the halves of the blade shut together quickly and capture the insect. After digesting the insect, the trap opens for more victims.

Some plants have leaves developed into tubes or urns for the same purpose. These so-called *pitchers* contain some water at their base, and have various means of attracting insects and causing them to fall into the water where they are drowned and afterward digested. The reason for these peculiar modifications is that these plants live in regions poor in nitrogen and other proteid elements, and as the soft parts of the insect bodies are mainly proteids, they have adapted themselves to this means of supplementing their scanty food supply.

QUESTIONS

1. What is the epidermis of a leaf? What are stomata? What is their use? What are guardian cells?
2. What can be said of the number of stomata on a leaf? What is the advantage of the small size of the

stomata? State some ways in which the opening is protected.

3. What does the small picture on page 53 show?

4. In the illustration on page 54 have you traced out carefully every feature presented?

5. What and where are the palisade cells of a leaf? What are the intercellular spaces? How formed?

6. What is the particular function of each part of the leaf?

7. What is venation? What are the veins of a leaf? What is pinnately netted veining? Palmately netted veining? Pinnately parallel veining? Palmately parallel veining?

8. Have you studied carefully the picture on page 56?

9. What is the relation of all the green parts of a plant to the plant body? When can the work of the leaf best be accomplished? How is this demonstrated?

10. Why are green plants able to live without help from other organisms? What is meant by the power of organization in green plants?

11. What are the materials required by the plant? Where and in what form does it obtain them? Why can these substances be used only in the form of a gas or liquid?

12. What does the plant do with these inorganic compounds? What is a carbohydrate?

13. What is photosyntax? What is the mechanism for the work of photosyntax? Why must green plants have good leaf exposure?

14. Of what use are the carbohydrates in the nutrition of the plant? What are proteids? Are they dependent upon light for their formation?

15. What is digestion in the plant body? What is assimilation? What is the object of each of these processes?

16. What is illustrated by the diagram on page 58?

17. How does the plant obtain energy for all its work?

What is oxidation? What effect is produced upon the protoplasm by oxidation?

18. When does the plant respire? What is the comparison to be made between photosyntax and respiration?

19. What is to be said of the process of respiration in plants and animals? In what lies the real difference between green plants and animals?

20. What is metabolism? What is constructive metabolism? Destructive metabolism?

21. What is transpiration? How is it accomplished in the plant body? What is the source of the water? By what part of the plant body? What can be said of the amount of moisture thus given off by plants?

22. Upon what does the amount of water transpired depend? What is the fact of greatest importance in connection with transpiration?

23. Name the kinds of leaves. What is a simple leaf? What is a compound leaf? What is the chief characteristic of compound leaves? How are they distinguished from divided leaves?

24. What are pinnately compound leaves? Palmately compound leaves?

25. What other trees would show equally well the peculiarities illustrated by those in the picture on page 61?

26. What are bud scales? Tendrils? Spines? Scale leaves?

27. What are flytraps and pitcher plants? Why do these plants possess these peculiar modifications?

LESSON VI

THE FLOWER

The flower produced by plants is a stem, modified to perform a function different from that of ordinary stems. The object of the flower is to produce the seed, in order that the plant may reproduce its kind.

92. **The parts of a flower.**—The early trillium is an excellent flower for type study, but as it blooms only in early spring is not a very convenient example. The cultivated geranium may be used in its stead, but this flower is open to the objection that cultivation has brought about an alteration of some of the parts and several bunches of the flowers may have to be studied in order to see all the parts in perfection.

Beginning with the outermost part of the flower, a whorl of green leaf-like bodies may be made out. This is the *calyx*, and the separate divisions are *sepals*. The inner whorl of the flower, the colored part, is the *corolla* and the parts the *petals*. The calyx and the corolla together constitute the floral covering, or *perianth*.

Removing some of the petals and sepals without disturbing the remainder of the flower, two more sets of organs may be seen. The first of these sets consists of a whorl of stalked, narrow bodies, called *stamens*. Each stamen consists of two parts, the smooth stalk or *filament*, and the yellow, two-lobed body on the filament, the *anther*.

If the anther is not too old, its parts may easily be distinguished. A green extension of the filament lies along one side of the anther, this is the *connective*. The two large yellow lobes, between which the connective lies are

called the cells of the anther, and these cells are filled with a yellow, more or less cohesive substance, the *pollen.* Under the microscope this is shown to consist of spherical bodies called *pollen grains.* In the older anthers it may be seen that the cells have broken open and have allowed the pollen to escape.

The innermost organ (sometimes several, sometimes but one) is the *pistil.* This consists of an enlarged por-

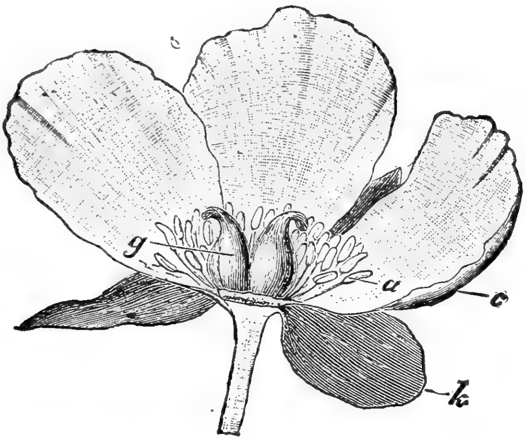


FIG. 200. A flower of peony, showing the four sets of floral organs: *k*, the sepals, together called the calyx; *c*, the petals, together called the corolla; *a*, the numerous stamens; *g*, the two carpels, which contain the ovules.—After STRASBURGER.

tion, the *ovary,* above this a slender stalk, the *style,* and upon this a structure having a number of divisions, the *stigma.*

With a sharp knife make a transverse section of the ovary, and note that it is divided into a number of compartments or *cells.* In each one of the cells are several rounded bodies, the *ovules,* and these ovules are attached to a portion of the inner area of each cell termed the *placenta.*

The ovary is the part of the flower which develops into the *fruit* and the ovules develop into *seeds.* But the ovules will not so develop unless *fertilized.* The process of fertilization will be described further on in the work.

All the parts of the flower are borne upon the end of the stem, which is more or less enlarged for their reception, and is then called the *receptacle.*

93. **Variation in floral organs.**—The floral organs are subject to numerous variations, in number, size, color, form, texture and so on. These variations can be only briefly indicated here. Many of the terms given are self-explanatory, in other cases, Webster's dictionary will give their botanical meaning.

(1) *Calyx.*—The sepals of the calyx may be distinct, as in the geranium, then the calyx is said to be *polysepalous.* When the sepals are united as in the fuchsia, the calyx is *monosepalous* or *gamosepalous.* The sepals in different flowers vary much as to form, color, texture and the like.

(2) *Corolla.*—The corolla, like the calyx, is polypetalous, or monopetalous (gamopetalous). The variations in the *form* of the corolla are more numerous and striking than in the calyx. The corolla may be tubular, funnelform, bell-shaped, labiate, salver-shaped, rotate, papilionaceous, etc. The *petals* may be placed on the receptacle (hypogynous) or upon the calyx (perigynous). The number, color, and shape, of the individual petals also varies greatly.

(3) *Stamens.*—The number and length of the stamens vary, and they are said to be opposite or alternate in their position with reference to the parts of the corolla. They may be placed upon the calyx (perigynous), the petals (epipetalous), or the receptacle (hypogynous).

Sometimes the stamens are united by their filaments (monadelphous, diadelphous, etc.) or they may be united by their anthers (syngenesious) or may be distinct. The attachment of the anther to the filament is *innate, adnate,* or *versatile.* The pollen of the anther is spoken of in regard to the color and abundance. The filaments are described in regard to length, form, surface, and color.

(4) *Pistil.*—The stigmas and styles are described regarding number, form, color, surface, division.

The ovaries vary as to the number, size, form, surface, and position. The ovary when free from the calyx is said to be *superior,* when united with the calyx, so that it seems to project below it, it is said to be *inferior.* In a cross section, the ovary may be found to vary in regard to number of cells, placentae, and number and size of ovules. The placentae are *parietal, axile,* or *free central,* accordingly as the ovules are attached (1) to the outer walls of the ovary, (2) the inner angles formed by partitions, or (3) on a central axis which is not united by partitions with the outer walls.

If there is but one cell, one placenta, one style, and one stigma, the pistil consists of but a single *carpel* or pistil leaf, and is said to be a *simple pistil.* If there are two or more cells, placentæ, styles, or stigmas, the pistil is made up of more than one carpel and is *compound.*

94. **Variation in flowers.**—When a flower has both stamens and pistils, it is a *perfect* flower. If in addition to these it has both calyx and corolla it is a *complete* flower. If the sepals are equal in form and size, and the same is true of the petals, the flower is a *regular* flower. Flowers may be *im*perfect, *in*complete and *ir*regular.

One of the most common and most puzzling ways in which a flower may be incomplete is to have the corolla lacking. In some flowers, as in the lily, the floral envelopes are all alike, all being uniformly large and brightly colored. This is generally termed a perianth. In other flowers both floral sets may not appear, and in that case it has become the custom to regard the missing set as the corolla, and call the remaining one the calyx, even though it is large and very brightly colored. Such flowers are called *apetalous.* It is not always possible to tell whether a flower is apetalous, or is simply one whose perianth has not yet differentiated into calyx and corolla. Often in a perianth the position of the parts is like that of a calyx and a corolla, while in an apetalous flower there is no such regularity of position.

Occurring very frequently are flowers having either stamens or pistils lacking. Upon a single plant may be found flowers having only stamens, others having only pistils. These flowers are called *staminate* and *pistillate*. They may occur upon the same plant, as in the elm, or upon entirely separate plants of the same species, as in the willow. Those plants which have both kinds are called *monoecious* (of one household); when flowers are upon two separate plants, they are said to be *dioecious* (of two households).

95. **Inflorescence.**—Flowers are usually borne near the top of the plant, since the plant must grow before it can bloom. Often they are produced in great numbers. The result is then that the flowers often must stand very close together, forming a cluster.

Certain definite or well marked types of flower clusters have received names, but the flower clusters which perfectly match the definitions are the exception rather than the rule. Some of the more common forms of clusters are the raceme, spike, head, catkin, corymb, umbel, and cyme. Examples of these in order of their mention are, lily of the valley, mignonette, clover, pussies of willows, bridal wreath, carrot, and apple.

The mode or method of flower arrangement is known as the *inflorescence*. The inflorescence may be either *clustered* or *solitary*.

96. **The essential organs.**—The stamens and pistils are both directly concerned in the production of the seed and so are called the essential organs of the flower. Some plants consist of but the two sets of organs, without any of the floral envelopes.

97. **Nonessential organs.**—The calyx and carolla are considered the nonessential organs as they are not directly concerned in the production of the seed. But they have several important uses, such as serving to protect the essential organs in the bud, and may also, when fully developed, by their form, size, and position, protect the essential organs against rain, wind, and undesirable insect visitors.

A third use of these organs is in connection with the process of pollination. In order that an ovule may be fertilized the pollen of the flower must be transferred to the stigma, of a different flower usually. Insects are often the agents by which the transfer is accomplished, and the bright color of the nonessential organs serves as an attraction, while their form, size, and arrangement may be such that insects of this kind will find a resting place while at work.

98. **The flower a modified branch.**—That the flower is a branch may be shown by several facts.

(1) It develops from a bud which is at first indistinguishable from a leaf bud, and may be either axillary or terminal in its location as is the leaf bud.

(2) The parts of the flower are modified leaves. In many flowers as the cactus, there is often a perfect gradation from small leaves through sepals to petals. Sepals and petals also often resemble leaves in form and venation, and the sepals also have the color and function of the leaf.

The stamens and the pistils may be proven to be greatly modified leaves, in such flowers as the double rose, the white water lily, or the peony. Here some of the stamens are partly developed into petals, in the water lily the gradation is often perfect. In many double flowers all the stamens generally have become petals. The structure of a stamen is not unlike that of a leaf; the filament corresponds to the petiole, the connective to the midrib, the cells of the anther to the two halves of the blade.

The structure of a pistil is also like that of a leaf folded and united at the edges. The style corresponds to the tapering apex, the tip of which forms the stigma.

(3) All the parts of the flower sometimes revert to true leaves. This is seen in the case of the *green blossoms* of the strawberry.

(4) In rare instances buds develop in the axils of the parts of the flowers, as they do in axils of leaves, and

leafy branches or flowers will grow out of the flower. The geranium often exhibits such a phenomenon.

99. **Fertilization.**—By fertilization in seed plants the botanist means the union of a generative or male cell from the *pollen grain* with an *egg cell,* which is found in the ovule. (See page 21.) This gives rise to a cell which contains material derived from the pollen grain and from the egg cell.

An ovule is a body with a stalk which fastens it to some portion of the cell of the ovary. Entrance to the interior of the ovule is obtained through an opening at one end. Inside is the embryo sac and inside this, at the end nearest the opening, is the egg cell or oosphere.

Each pollen grain is a cell, with distinct cell walls, and a dense nucleus, imbedded in the protoplasm.

The pollen grain is deposited upon the sticky stigmatic surface, by various methods which will be described in the next lesson. Shortly after its deposition it germinates, that it, the outer wall breaks and the contents, including the nucleus, are pushed out in the form of a slender *pollen tube.*

This pollen tube penetrates the tissue of the style, goes into the cavity of the ovary, enters the opening of the ovule, then penetrates the wall of the embryo sac, where the oosphere awaits it. While the pollen tube has been lengthening, its nucleus has divided into two nuclei, and when the pollen tube comes in contact with the oosphere, one of these nuclei unites with the oosphere, and the latter is *fertilized,* and an oospore is formed.

This oospore now grows by cell division, developing into the *embryo plant* which is found within the *seed.* So a seed is not a simple reproductive body, but is a very complex structure, containing the beginnings of all the plant structures, together with more or less nutritive material for the nourishment of the embryo when it first begins to grow and is unable to obtain nourishment from the surrounding medium.

The length of the pollen tube varies with the length of the style, and the length of time it takes the tube to grow also varies considerably. In some cases it requires twenty-four hours or more, in others, notably those plants having very long styles, the process requires from one to three days. But no matter what the length of the style may be, nor what the length of time may be, the process of fertilization must be accomplished essentially as described above, or there will be no seed.

The necessary feature in fertilization is the union of the essential contents of two cells to form a new one from which the future plant is to spring. It will be remembered that this kind of union was found to occur in the lower plants, resulting in the production of a spore capable of growing into a new plant like that which produced it. (See page 8.)

It will be noticed that nearly every plant produces a vast number of pollen grains, when compared with the number of seeds which finally result, or with the number of ovules. Only one pollen grain is necessary to fertilize each ovule, but so many of them are lost in the transfer from anther to stigma, that in order to provide for the propagation of the plants, they must produce many more of pollen grains than of ovules. The ratio varies greatly, from being as low as 8 grains to an ovule, to as high as 7,000 to 1, and in some plants even much greater. The differences depend upon the way in which the pollen is carried from the stamens to the pistil.

100. **The seed.**—The seed, it has already been stated, is a development of the ripened, fertilized ovule. The seed contains the miniature plant or *embryo.*

The outer coating of the seed is called a *testa,* and this hermetically seals the structure within so that development and activity are checked, and the seed rests until it is placed under favorable conditions for germination. This testa is variously developed in seeds, sometimes smooth and glistening, sometimes rough. Sometimes it

develops prominent appendages which aid in seed dispersal, as the tufts on the seed of the milkweed and cotton.

The embryo usually has three parts which have received names: (1) the little stemlet or *hypocotyl,* whose pointed end is the root tip, (2) the seed-leaf or *cotyledon* (usually one or two, and (3) the bud or *plumule* lying between the cotyledons. These parts are well seen in the common bean, particularly after the seed has been soaked for a few hours.

Every seed is provided with a greater or less amount of food for the nourishment of the germinating plant. The most common form of this food is starch. This food may be stored in the large, thick cotyledons, as in the bean, or it may be outside the small cotyledon, as in the Indian corn.

The vitality of the seed varies greatly. Some seeds maintain life but a short time, a few weeks or even days, and others will maintain it for years.

101. **Germination of the seed.**—When the embryo plant is supplied with moisture, warmth, and air (oxygen) it is aroused from its dormant state and grows. It does not truly germinate, for germination started when the oospore was formed, but it was checked during the resting time of the seed. The embryo lives for a time on the stored food and gradually the little plant secures a foothold in the soil and gathers food for itself.

The first part of the young plant to emerge from the seed is the tip of the hypocotyl, which is to develop the root system. Shortly after, the stem tip arises from the seed, and bears with it to the light the cotyledons and the first pair of true leaves which formed the plumule in the seed. The cotyledons do not emerge from the seed in all cases. From the very beginning of the emergence of the plant from the seed, the root tip seems to be very sensitive to the earth influence and also to moisture influence, for no matter what the position of the seed may be, a curvature is developed which directs this tip towards and into the soil. And likewise the stem tip is very sensitive to

light influence, being guided in a general way towards the light.

QUESTIONS

1. What is the flower of a plant? What is its function?

2. What is the calyx? What are sepals? What is the corolla? What are petals? What is the perianth?

3. What is a stamen? What are the parts of a stamen? What are the parts of the anther? How does the pollen get out of the anther?

4. Have you studied the excellent illustration of the parts of a flower shown on page 67?

5. What is the pistil? What are its parts? What are the parts of the ovary? Into what does the ovary develop? Into what do ovules develop? When do they so develop? What is the receptacle?

6. What are the variations to be found in the calyx? In the corolla? In the stamens? In the pistils?

7. What is a simple pistil? A compound pistil?

8. What is a perfect flower? A complete flower? A regular flower? An imperfect flower? An incomplete flower? An irregular flower?

9. When a flower has but one set of floral envelopes, which is the one that is lacking? What is an apetalous flower? What is the difficulty in recognizing an apetalous flower?

10. Why are flowers usually borne near the top of the plant? Why are they often in clusters?

11. What is inflorescence? What are the main classes of inflorescence?

12. What are the essential organs of the flower? Why are they essential? What are the nonessential organs? Do these nonessential organs have any use?

13. What are some of the facts that prove the flower to be a modified branch?

14. What is meant by fertilization in seed plants? What is the structure of the ovule? What is the structure of a pollen grain?

15. Why is the pollen grain deposited upon the stigma of a flower? What becomes of it when so deposited?

16. What is a pollen tube? What is the oosphere?

17. How does the pollen tube come in contact with the oosphere? When is the oosphere fertilized? What is then formed?

18. How and into what does the oosphere develop? What is a seed? How does a seed compare with a spore?

19. Upon what does the length of a pollen tube depend?

20. What is the necessary feature in fertilization? Where else was this same process noted?

21. Why does a plant produce usually so vast a number of pollen grains?

22. What is the embryo of a seed?

23. What is a testa? What is its function?

24. What are the parts of the embryo?

25. What is the use of the starch and other food materials in the seed?

26. What is necessary for the germination of the seed? When does germination really begin?

27. What are the steps in the early development of the young plant?

LESSON VII

SPERMATOPHYTES

102. **Angiosperms and gymnosperms.**—In the following pages, not much more than a mere statement of the main characteristics of this great group can be given.

The main points of distinction between the two great classes of Spermatophytes, the angiosperms and the gymnosperms, has been expressed in the statement that the gymnosperms bear naked seeds, while the angiosperms have the seeds in some form of a closed ovary. A pine cone and the pod of a bean will illustrate this. The cone, in the sense that it is a product of the changes brought about by fertilization, is the fruit of the pine and is made up of a number of scales. Each of these scales bears at its base, two seeds which are attached to the surface of the scale, but have no envelope about them. In the bean the walls of the fruit make a sac in which the seeds of the plant are completely inclosed.

103. **Gymnosperms.**—The gymnosperms are the older class of the Spermatophytes, and occupied a much more important position in the earlier geological periods, forming a characteristic feature of the luxuriant vegetation of the coal measures. They are now reduced to a few hundred species. Being the older class, they exhibit a much closer alliance with the Pteridophytes than do the angiosperms. They are all woody plants, with secondary growth in thickness, but differ widely in habit. Some are tree forms, others shrubby, and some are high climbing vines. The leaves are simple, and are then usually needle-like, as in the pine, or scale-like, as those of the arbor vitae, or they may be pinnate as are those of the cycads.

The flowers of the gymnosperms are characteristic organs. These are of two kinds, *staminate* and *pistillate,* and the plants may be monoecious or dioecious. The inflorescence is cone-like in general structure, the pistillate being more distinctly so. The ovules are naked and are borne in the axils of the scales of the young pistillate cone, and have no style or stigma. The seed into which the ovule develops is usually winged.

The staminate flowers are simple stamens borne under scales which form small yellow catkins. After shedding the pollen, the catkins soon fall. The pollen is dry, very abundant, and each grain bears two little wings to help in its transportation through the air. The pollen is borne to the pistillate flowers by the wind, and slides down the scale to the ovule, where it lies in drifts. The pollen tubes then develop and entering the opening in the wall of the ovule, unite their nuclei with the oosphere and fertilization is accomplishd. The pistillate cone persists upon the tree, and its scales become very hard. While the ovule is developing the scales of the cone close over it, but when it has ripened into a seed the scales open again and permit the seeds to fall out.

104. **The groups of gymnosperms.**—The most important groups of the gymnosperms are the cycads and conifers (cone bearers). The cycads are exclusively tropical and are found in both the western and eastern hemispheres. They resemble tree ferns in their general appearance, structure, and dimensions, but their distinctive characteristic, and the one which places them with the gymnosperms, is the production of naked seeds. There are but eighty species of the cycads in existence now, but in the earlier geological times they grew in large numbers and formed a large part of the vegetation of all zones, as proved by their fossil remains.

105. **The conifers.**—The conifers are strictly temperate in their distribution, and are found in both the north and south temperate zones. The genera are unlike in the different zones, the most characteristic one of the north

temperate is *pinus,* in which all our pines are grouped. The species of conifers are comparatively few in number, but the number of individuals is so great that great forests are formed in these regions.

In the group of conifers are found besides the pines, the spruces, cedars, cypresses, firs, yews, and larches. The group is generally known as *evergreens,* but some of them are not really evergreen, the common larch or tamarack drops its leaves at the approach of winter just as do most of the angiosperms.

In this group are found some of the largest trees in the world, the giant redwoods or sequoias of California. These grow to an enormous height and are excelled only by the eucalyptus of Australia. Many of the sequoias are from fifteen to twenty centuries old.

The fruits of conifers are not all alike, those of the cedars seeming not to have the cone-like structure, but close examination of the fleshy berries will show that they are made up of scale-like bodies, enveloped in fleshy coverings. On some of the conifers the fruit is reduced to but a single scale.

106. **Angiosperms.**—These are the most highly developed of all plants, and have formed the chief part in the vegetation of the later geological ages. The two great groups of this class are the monocotyledons and dicotyledons. (See page 34.) These two groups exhibit several contrasting characters which are always stated to distinguish the groups.

The monocotyledons have but one cotyledon or seed leaf, the stems have the bundles scattered irregularly throughout and have no annual increase in diameter, and the leaves have what is known as the *closed* system of veining. The dicotyledons have two (or more) cotyledons, have the bundles in the stem arranged in definite rings, the stems have an annual increase in diameter, and the leaves are netted-veined.

In the monocotyledons the flowers are usually in 3's, that is the sepals, petals, stamens, etc., are three, or some multiple of three in number. In the dicotyledons the majority of the flowers are in 5's, though some of the important orders have flowers in 4's or 2's, or even 3's.

The system of veining in the leaves of these two groups was once distinguished as parallel-veined for the monocotyledons, and netted-veined for the dicotyledons. But many of the monocotyledons, particularly the tropical species, have netted-veined leaves. But all monocotyledonous leaves, whether netted or parallel veined, have a large vein running around the edge of the leaf which catches up all the small veins and prevents them from running out to the edge of the leaf. This is the *closed* system. In the dicotyledonous leaves, the veins run out to the edge of the leaf, and the edge is more or less irregular. But of the characters stated above, no one of them is absolutely distinguishing except the first.

107. **Monocotyledons.**—This is the older group of the angiosperms and is the less highly organized of the two. Several of the families of this group are world wide in their distribution. These are the ones that have succeeded in adapting themselves to every condition. Four of these families form about one-half of the twenty thousand species of monocotyledons. They are the grasses, sedges, lilies, and irises. The distribution of these is fairly uniform, that is, there is a natural massing toward the tropics. Two species in the temperate to three in the tropics represents a natural distribution. The monocotyledons of the temperate regions are never of large size, but many of those of the tropics, as the palms, often form large trees.

Some of the families of this group are of great economic importance. The grasses include some of our most important cereals, as wheat, rye, oats, barley, corn, the sugar canes, the bamboo, and our pasture grasses, all of which are of immense value. Some of the lily family are cultivated as vegetables, for example the onion, and asparagus.

108. **Dicotyledons.**—The dicotyledons are the greatest of all the groups of plants, both in rank and numbers. Nearly all botanists divide them into three divisions based on floral characters. These are the apetalous, the polypetalous and the gamopetalous divisions. The first contains the flowers having no corolla, the second, the corolla with separate petals, and the third, the petals all united in one piece. A new grouping has been made by more modern authors into archichlamydeæ and sympetalæ. The first includes the apetalous and polypetalous divisions, while the gamopetalous division is placed in the second group. The archichlamydeæ contain about one hundred sixty families while the sympetalæ have about fifty.

The archichlamydeæ contain about forty thousand species, many of which are tree forms. There is no family having a world wide distribution in this group, but it is predominantly tropical. The leguminosæ, the order to which the bean and pea belong, is the greatest order of the group.

The sympetalæ also contain about forty thousand species, mostly of the smaller forms of seed plants. Three great world families are found here, these are massed chiefly in temperate zones, but found also in the tropics and arctic zones. They are the composites, the mints, and the plantains.

No study of the different families of this group and the individuals comprising them can be given in this course. That must be a matter of individual work, gained by an actual study of the plants together with some good guide for plant analysis.

109. **Classification.**—The classification of plants is based upon their actual relationships to each other. In each of the four great groups already mentioned (see page 5) there are placed those plants which show points of great similarity but at the same time have marked differences from the group above or below them. This can be illustrated by the following outline:

(1) Thallophytes, all have a thallus, but no archegonia.

(2) Bryophytes, all have archegonia, but no woody structure.

(3) Pteridophytes, all have woody structure, but no seeds.

(4) Spermatophytes, all have seeds.

110. **Cryptogams and Phanerogams.**—The first three groups are classed under one head as Cryptogams, a term meaning *hidden sexual reproduction,* while the plants of the remaining group are called Phanerogams, meaning *evident sexual reproduction.* Professor Coulter of Chicago University states that the names should be reversed, for the sexual reproduction is much more evident in the Cryptogams than it is in the Phanerogams. These great groups are sometimes called the *flowerless* and *flowering* plants, but here also Professor Coulter states that the terms are incorrect, for in the popular sense all Spermatophytes do not have flowers, and in another sense the spore producing organ of the Pteridophytes is a flower.

111. **Flower grouping.**—To follow out the idea of further classification in each group we will take the Spermatophytes for illustration. Even those who have never made a study of botany have undoubtedly recognized the fact that all the plants with which they are familiar in a general way are not alike, but are readily associated into groups. The botanist groups these Spermatophytes first into two great classes, gymnosperms and angiosperms. The gymnosperms are the plants bearing naked seeds, while the angiosperms have the seeds inclosed in a pod or covering made of the walls of the ovary. Each of these classes is divided into several great groups. Under the gymnosperms we find the cycads and the conifers or cone bearing trees, and other groups. Under the angiosperms are the groups of monocotyledons and dicotyledons.

The following table will represent the classification so far as we have now carried it:

- Cryptogams
  - Thallophytes.
  - Bryophytes.
  - Pteridophytes.
- Phanerogams
  - Spermatophytes
    - Gymnosperms
      - Cycads.
      - Conifers.
    - Angiosperms
      - Monocotyledons.
      - Dicotyledons.

112. **Order.**—Taking the dicotyledons as a basis for further grouping, we find that all the plants here may be placed in a number of large groups, these we call *orders.* For instance the strawberry, apple, rose, plum, and peach, are all distinctly related to each other, so we place them in the order rosaceæ. The sunflower, daisy, and dog fennel, are examples of plants related to each other in another way and these are placed in the order compositæ.

113. **Family.**—Each order may now be grouped upon a basis of certain related facts into *families.* For instance the order sapindaceæ to which our maples belong, is divided into the bladdernut family, the soap berry family and the maple family. Many authors will still give the order and the family as interchangeable terms, but the general tendency in later times is to consider the order as a more general, and the family a somewhat more specific term.

114. **Genus, species, variety.**—In the family also different groups may be made of plants possessing more closely related characteristics, and each of these groups will be called a *genus* (plural genera). It is well to state that orders may contain one family, and a family may sometimes have but one genus. The individual members of a genus will not resemble each other in every particular and these individuals make up the *species.* If one species varies from another in a slight degree we may have a *variety.*

For illustration of these points we may take the order violaceæ, which has but one family, the violet family, and one genus viola. Under the genus viola are a number of different species, as the common blue violet (V. palmata L.) the birdfoot violet (V. pedata L.) the pansy (V. tri-

color L.). The common blue violet exhibits some variations and this is classed as a variety, viola palmata, variety cucullata, Gray. After the scientific name of the flower often comes the abbreviation of the name of the botanist who is authority for it, as in viola palmata L., the L. stands for Linnaeus.

The following outline will show the remaining points in classification:

- Dicotyledons
  - Order Violaceæ.
    - Violet Family
      - Genus Viola
        - Species.
        - Viola Palmata,
        - Viola Palmata, var. cucullata, Gray.
        - Viola tricolor.
  - Order Rosaceæ.
  - Order Compositæ.

These points are usually written in the following form:

Order—Violaceæ.

Family—Violet.

Genus—Viola.

Species—tricolor.

Scientific name—Viola tricolor.

Common name—Pansy.

It will be noted that the scientific name of a plant is a combination of the generic and the specific name, and that the specific name is never written with a capital, although the other designations very frequently are so written.

Different authorities will be found to vary greatly upon minor points in classification, but the *general plan* will always be found to be the same with all authorities.

QUESTIONS

1. What are Spermatophytes? What are the two great classes of Spermatophytes? What is the main point of distinction between them?

2. Which class of Spermatophytes is the older? Has it always possessed the same relative importance that it now holds?

3. Why do gymnosperms exhibit closer alliance with the Pteridophytes than do the angiosperms? What is the habit of the gymnosperms? What kind of leaves do they have?

4. What kinds of flowers do gymnosperms have? Where are they borne? Where are the ovules borne? Where are the stamens? What is the character of the pollen?

5. How is the ovule fertilized? What is the cone of the gymnosperms?

6. What are the most important classes of the gymnosperms? Why are cycads not classed with the ferns? How does the present number of species of cycads compare with the number in existence during earlier geological periods?

7. Where are the conifers found? What is the characteristic genus of the United States? What can be said of the number of species of the conifers?

8. What plants aside from the pines are grouped under the conifers? Are the conifers all evergreens? Where do we class the giant redwoods of California? Are they the largest trees of the world?

9. How do the fruits of conifers compare with each other? Why do the cedars develop the fleshy coverings?

10. What is the rank of the angiosperms? What are the two great classes under this head?

11. How do we distinguish a monocotyledonous plant from a dicotyledonous plant? What is the closed system of veining?

12. How do the monocotyledons compare in age and organization with the dicotyledons? What families in this group are world wide in their distribution? How does the distribution and size of monocotyledons in temperate regions compare with that of tropical regions? Of what economic importance are some of the families of the group?

13. What is the rank of the dicotyledons? What are the three divisions usually made of this group? What is the new arrangement of the group?

14. Upon what is the classification of plants based?

15. What are Cryptogams? Phanerogams? Why are they so called? Why should the terms be reversed?

16. What are the great groups of the Spermatophytes? How are they divided?

17. What is an order? A family? A genus? A species? A variety?

18. How is the scientific name of a plant constructed? What is the meaning of the abbreviation after the scientific name?

LESSON VIII

ECOLOGY

PLANT SOCIETIES. SEED DISPERSAL

115. **Ecology.**—One of the more recent developments in botany is the detailed study of that portion which has to do with the way in which plants get along with their plant and animal neighbors. This is called *ecology*. It treats especially of the way in which the plants adjust themselves to the nature of the soil and climate in which they live. It will easily be seen that much of what has been said in previous lessons is really ecological botany.

116. **Plant societies.**—Plants, in their distribution over the earth's surface, are arranged according to a definite plan. All plants that can adapt themselves to certain conditions of soil, temperature, light, etc., will be found grouped together wherever these conditions occur, and will form what is known as a *plant society*. Cat-tails often grow in swamps in great number, but among the cat-tails and down near the surface of the swamp will be found many other species of plants, which adapt themselves to the same conditions. These will form a plant society.

Wherever the same conditions are found, there the same species of plants will be apt to occur, or, if not already there, will flourish when transplanted from other localities. Usually related species of plants are not to be found in the same society, because the competition between them is too great, so a plant society is most often made up of unrelated species.

117. **Ecological factors.**—But very little is known definitely of the operation of the factors which determine plant societies. About all that is known is that the water, soil, heat, and light conditions surrounding a plant are of vast importance to it, and that it changes its nature as it is subjected to these factors in varying degrees.

Some plants require large quantities of water, others get along with very small quantities. As the first plants were aquatic, those doing without water must be specialized forms, which have gradually adapted themselves to live with but little water.

Heat is also a factor of great importance not only as it determines the great zones of vegetation on the earth's surface, but as it affects local areas. Each plant has its own range of temperature, sometimes varied, sometimes very much restricted.

The soil is a very important element in determining the value of plant life. As soils vary in their ability to receive and retain water, in the amount of food which they hold for plants, and in compactness, so will the plant societies vary, some being able to live upon one kind of soil, others on entirely different kinds.

Plants are sun loving and shade loving as they require greater or less amounts of light. Their leaves are arranged in such a manner as to present the greatest amount of surface to the light, and so it becomes evident that light also is a great factor in the life of plants.

Wind should be mentioned as an important factor in addition to the ones already cited. In regions where there are strong prevailing winds, the transpiration of plants is very greatly increased, and so plants must learn to adapt themselves to this condition.

All of these factors are instrumental in determining plant societies, but not in the same degree in all localities, and so there can be various combinations. Any factor might be used as a basis for grouping these societies, but for convenience they are classified in regard to the amount

of water they require. Grouped with reference to this factor in their lives, all plants may be classed as:

(1) Hydrophytes, or water loving.

(2) Mesophytes, or plants which thrive best with a moderate supply of water.

(3) Xerophytes, or drought tolerating plants.

(4) Tropophytes, or seasonable plants which are hydrophytes or mesophytes part of the year and xerophytes during another part.

(5) Halophytes, or salt marsh plants and other species which can flourish in a soil impregnated with saline matters.

The greatest difficulty in ecological classification arises from the fact that it is very hard to determine just what amount of water plants have in a region. The nature of the soil, the temperature of the soil and air, and the prevalence or absence of drying winds, fogs and heavy dews must be known. So the determination of a plant society is not a matter for hasty decision, but requires most careful study.

118. **Hydrophytes.**—Hydrophytes may thus be either aquatic or land plants. The aquatic hydrophytes are illustrated by the pickerel weed, the duckweed, and the pond lily, while the liverworts, mosses, and ferns are land hydrophytes, preferring damp air and soil. All of these plants transpire very freely.

119. **Mesophytes.**—Mesophytes make up the majority of the wild and cultivated plants of the United States. The mesophytic condition is the arable condition. If an area is hydrophytic, and is to be tilled, it is drained until it becomes mesophytic; if it is xerophytic it is irrigated and forced to assume mesophytic conditions. The typical mesophyte of the greater part of the United States is an annual, since most perennials and biennials pass the winter in a xerophytic condition.

120. **Xerophytes.**—A xerophyte is a plant which can get along with a scanty supply of water. To be able to endure this condition, xerophytes have developed many

adaptations. The two main things which a xerophyte must be able to do is to store up a considerable amount of water and give off but very little. So they have, first of all, reduced their surfaces for transpiration.

Some plants, as the cactus, have dispensed with leaves entirely, and have made the green covering of the stems do the work of leaves. Others have been protected from losing their scanty supply of water by having the leaves rolled up with the transpiring surface on the inside. Many species which bear leaves shed most of them at the beginning of the dry season, and remain in a half dormant condition for long periods.

The roots and stems of xerophytic plants are usually thick and fleshy and commonly contain large amounts of water. The epidermis of the leaves and stems is generally very thick and thus prevents transpiration. Some few xerophytes, as the yeast plant, are able to exist for a long time in a thoroughly dried state and will then revive on being placed in contact with water under the right temperature.

121. **Tropophytes.**—These seasonal plants are found in regions where there is a decided change of seasons. The deciduous trees of our own regions are very good illustrations, as are also all plants which live over winter by means of a fleshy bulb, root or tuber which stores food and water underground, as the tulips, peonies, potatoes, carrots, and beets. All these plants have a large transpiration surface during the summer and prepare for winter by the dropping of leaves, or the dying down of herbaceous parts above the ground.

Plants which prepare for existence during the dry season, as do those of southern California, are also tropophytes.

122. **Halophytes.**—The salt marsh plants and those which live in the alkali lands of the west are true halophytes. Most of these plants have a truly xerophytic structure, even though they may live with their roots in the salt water. The reason for this is that the presence

of salt in the water makes it almost impossible for osmosis to take place and so the halophytes get very little water. The mangrove of Florida is one of the best illustrations of halophytes.

123. **Other ecological subjects.**—Many other subjects are discussed in plant ecology. Some have to do with the way in which plants protect themselves against animals and other plants; some treat of the manner in which plants disperse their seeds. How plants are pollinated and how they adjust themselves to get the best exposure to light are two other great ecological subjects. All these represent phases of the plant's struggle for existence, and discuss the adaptations which plants have been compelled to assume in order that they may successfully compete with their neighbors.

124. **Seed dispersal.**—No one ecological subject is of more interest than the manner in which the various plants disperse their seeds. A comparatively wide dispersal of seeds is necessary with most plants, for by being carried away from the neighborhood of the parent plant they get away from competition. Many seeds and fruits are of such a character as to increase their chance of wide dispersal.

125. **Adaptations for dispersal.**—Seeds are very rarely light enough to be carried by the air without some special adaptations. These may take the form of inflated coats, as in the bladder nut, or they may be appendages, such as the wings of the elm, maple, and catalpa seeds, or tufts of hair, as illustrated by the thistle, milkweed, and dandelion. Another type of dispersal by air is illustrated by plants which develop a nearly globular form of the plant body when dried, and breaking off near the surface of the soil, are blown by the wind for long distances. One of the best illustrations of this is the Russian thistle, which sometimes scatters two hundred thousand seeds from a single plant over a wide area. The tumbleweeds of the western prairies scatter their seeds in the same manner.

Certain plants have peculiar seed pods which warp or dry unequally and when subjected to even very slight disturbance, will burst and scatter the seeds. The seeds of our common violets, wild geraniums, and jewel weeds are scattered in this manner.

Animals of many kinds are very active agents in the transportation of seeds. Birds particularly, but other animals also, are attracted by the bright colored parts of many fruits. These they eat and either reject the seed because of its unpleasant taste, or pass it with the flesh of the fruit into the alimentary canal. Many of these seeds are so hard as to resist the action of the digestive juices and are passed from the canal in a condition suitable for germination. Grapes and junipers are plants that are very widely distributed in this way.

Water birds often carry seeds of many plants in the mud which adheres to their feet, and as they are usually high and strong fliers they will often carry those seeds long distances before depositing them. In two places in Iowa the seeds of the yellow lotus, a southern plant, have obtained a good foothold, and it is supposed that they were brought to the ponds in which they are found by wild ducks which stopped there during their spring migrations.

Other plants have their seeds variously provided with hooks, spines, glands, etc., by which they adhere to the bodies of animals and are thus carried about. The burdock, sticktight, cocklebur, and sandbur, are familiar illustrations of these kinds of plants.

Often seed carrying is purposely done by animals. In the other cases they have been unconcious agents, but sometimes they carry fruits and nuts to their nests or houses to store them for food. Squirrels and bluejays are often seen to carry acorns and other nuts and bury them for food. Sometimes these deposits are forgotten and thus much tree planting is done.

QUESTIONS

1. What is ecology? Of what does it treat?

2. What is a plant society? Where will we be likely to find plant societies that are similar to each other? Why are not related species of plants found in a plant society?

3. What are the important factors which determine plant societies? Why is it important to study the water supply in determining a plant society? The heat condition? Of what importance is the soil in this study? The light? Wind?

4. Upon what bases are plants classified ecologically? What are hydrophytes? Mesophytes? Xerophytes? Tropophytes? Halophytes?

5. In what lies the greatest difficulty in determining the correct ecological classification of plants?

6. What may be the location of hydrophytes? What are some aquatic hydrophytes? Some land hydrophytes?

7. Of what importance are mesophytes in the United States? What is the connection between the mesophytic condition and the arable condition of soils?

8. What is a xerophyte? What are the two main things which a xerophytic plant must be able to do? In what way have xerophytes adapted themselves to this condition? Why are xerophytic plants often leafless? What other changes are made in the amount of leaf surface?

9. What is the nature of the roots and stems in xerophytes? Of the epidermis? Why is the yeast plant a xerophyte?

10. What is a tropophyte? Where are tropophytes found? What are some of the tropophytes of our own region?

11. Where are halophytes found? Why have they usually a xerophytic structure?

12. What are some of the other subjects discussed in plant ecology?

13. Why is a wide dispersal of seeds necessary with many plants? Why do some plants have winged append-

ages or tufts of hair upon the seeds? What manner of dispersal is practiced by the Russian thistle?

14. How are seeds distributed by explosion of the pods? What plants are illustrations of this method?

15. In what way do animals assist in seed distribution? Why are many fruits brightly colored? How do water birds act as agents of distribution? Why are plants often provided with spines, hooks, and glands?

16. Is seed carrying ever done purposely by animals?

LESSON IX

ECOLOGY, CONTINUED

POLLINATION. THE LIGHT RELATION

126. **Pollination.**—Pollination is the transferring of pollen from the anther to the stigma, in order that fertilization may be accomplished. It was long supposed by botanists that the pollen of any perfect flower need only to be placed on the stigma to insure fertilization. But Charles Darwin in 1857 and 1858 stated, as the result of a long series of investigations, that many flowers were entirely dependent for fertilization upon the transference of pollen from one plant to another. It was also shown that in some cases where the plant might produce some seed if self pollinated, it would do far better if the seed were produced by the pollen from another plant of the same kind.

127. **Kinds of pollination.**—Pollination may be of two kinds, *cross pollination* and *self pollination.* Cross pollination it is supposed is by far the more common method, still many plants do bear flowers that are constructed for self pollination. One of the most common illustrations of this is the violet. It bears large, conspicuous flowers which are cross pollinated only, but down among the leaves will be found small inconspicuous flowers, which are supposed never to be open, and these produce large numbers of seeds. Flowers of this type, for the reason that they were supposed not to open, are called *cleistogamous* flowers. Recent investigations have shown that cleistogamy is much more common than has been

supposed and is practiced by a large number of flowers, aside from the violet.

A study of the pollination of the yucca and of figs (caprification) will give additional facts of interest regarding self pollination.

In cross pollination it is evident, that as there must be a transference of the pollen from one plant to another, there must be agents of transference. These are mainly wind and insects, though birds, snails, and water are also active agents with some particular types of plants.

Upon the basis of pollination, flowers may be divided into groups as *wind pollinated* and *insect pollinated,* and each group will exhibit its own characteristics.

128. **Wind pollinated flowers.**—All the grasses and by far the larger number of trees are examples of wind pollinated plants. The flowers in these cases are very inconspicuous, so much so that school children on beginning botany are often surprised to learn that the common shade trees and grasses have any flowers at all. These wind pollinated flowers are usually borne on exposed or elevated or lengthened structures, such as long flower stalks, or the stamens have very long filaments.

The stigmas are often very sticky, or are plumed, and thus adapted to catch the flying pollen grains. The pollen is very dry and light and is remarkable for its great abundance. This is necessary because with this method of transference so much of the pollen is lost. Everyone is familiar with the vast quantities sent into the air by our common ragweed. In pine forests the pollen is often produced in such abundance as to fall in showers from the tree. These *showers of sulphur* are often borne a long distance from the woods in which they are produced.

Wind pollinated flowers are also remarkable for the fact that they are usually very regular, and that they have no odor and no nectar. In many cases they appear on the plant some time before the leaves are developed.

129. **Insect pollinated flowers.**—In studying a plant from the standpoint of its surroundings no one thing is

more remarkable than its relation to its animal neighbors. This relation is productive of mutual benefit, for while the animal helps the plant to provide for its reproduction, the plant furnishes food to the animal.

In general it may be stated that the showy colors and markings of flowers, their peculiar shapes, and their odors, all serve as so many advertisements of the nectar or the pollen which the flower has to offer its insect visitors.

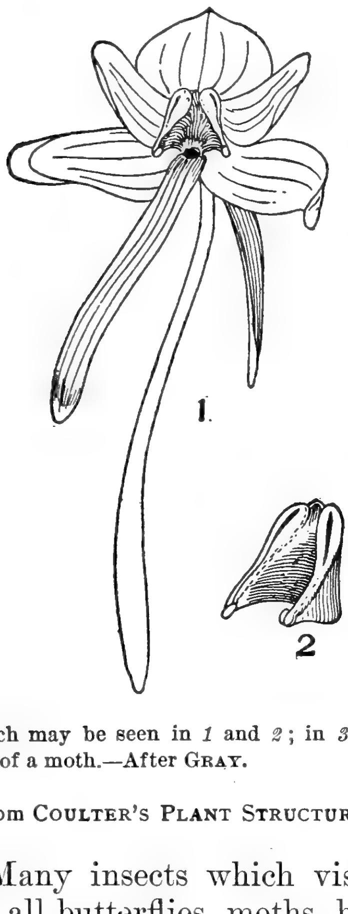


FIG. 235. A flower of an orchid (*Habenaria*): at *1* the complete flower is shown, with three sepals behind and three petals in front, the lowest one of which has developed a long strap-shaped portion (lip) and a still longer spur portion, the opening to which is seen at the base of the strap, and behind the spur the long inferior ovary (epigynous character); the two pollen sacs of the single stamen are seen in the center of the flower, diverging downward, and between them stretches the stigma surface; the relation between pollen sacs and stigma surface is shown in *2*; within each pollen sac is a mass of sticky pollen (pollinium), ending below in a sticky disk, which may be seen in *1* and *2*; in *3* a pollen mass (*a*) is shown sticking to each eye of a moth.—After GRAY.

Many insects which visit flowers have smooth bodies, but all butterflies, moths, bees, and many beetles, have the body more or less roughened or covered with scales or hairs, which hold a great deal of the pollen. Often the pollen is very sticky and adheres to the body of the insect

until it is brought in contact with the sticky stigma, which in such cases, is stickier than the pollen.

All flowers which depend upon insects to bring about pollination have showy colored floral envelopes. These colorings are not always brilliant, but enough so to serve as an attraction. It has been found that flowers with dull yellow, or brownish or dark purple corollas attract flies, while red, violet, and blue, are the colors by which butterflies and bees are more readily attracted. White flowers often are pollinated by night flying insects, the corollas being then very attractive.

Some recent experiments made upon insects serve to prove that many of them are either color blind or are very near sighted. If this is true, much of botanical literature upon pollination will have to be revised. But it has also been proven, that these same insects have remarkably keen scent and thus may be attracted to the flower by an odor which human beings are incapable of recognizing.

It is not to be supposed that the color in the corolla may not be of some service. Just what it is is not now known, but it may be that color in the flower serves some such purpose as does the green in the leaves. When we remember that these same colors are found in foliage leaves, the supposition does not seem at all improbable.

Many of the brilliantly colored flowers have very irregular corollas. This seems to render the flower more attractive and offers at the same time resting places for the insects while at the work of obtaining pollen or nectar. Sometimes the irregularity is such, as in the case of the flowers of the bean family, that the weight of the insect in resting upon it will serve to expose the stamens and make them come in contact with the insect's body.

Other brilliantly colored flowers are very regular, but in these cases the element of attraction has been considered in the grouping in clusters of a number of the flowers. The time saved in pollinating a large number of flowers in a cluster is of great value to the flower also. The

clover and nearly all the plants of the composite family, the sunflower, and the daisy are illustrations of these facts.

The odor of cross pollinated flowers is generally very noticeable. They are often, but not always, sweet scented. The hawthorn is an illustration of the carrion scented flowers, but it attracts many insects, nevertheless. The night blooming flowers have usually very strongly scented corollas.

Some, but not all, of the cross pollinated flowers have nectar glands or lines. These are collections of cells whose special function is the secretion of a sweet liquid which attracts the insects. This nectar when partially digested in the crop of the bee, becomes *honey*. On the petals of many flowers are to be noted lines and groups of lines, in striking contrast to the color of the petals. These are nectar guides, and followed by the insect, will lead it to the nectar secreting portions.

It is interesting to know that insects do not visit all flowers indiscriminately, but that certain flowers and insects have been adapted to each other's needs. So that sometimes certain families of insects are restricted to families of flowers, sometimes to genera and sometimes to single species. The orchids are the most highly specialized in regard to insect visits, and they are adapted to moths alone.

130. **Hybrids**.—Often pollen from one species of plant will prove potent upon the stigma of a different species. The resulting seed will give rise to a plant which combines the characteristics of the parent plants. Such a plant is called a *hybrid,* and this gives a clue to the methods used by florists in producing the vast number of new varieties of plants. The range of hybridization differs very widely in different groups of plants, in some it is very wide, in others very narrow.

131. **Protection against unwelcome visitors**.—Many insects which might visit a plant would be unwelcome visitors, for they would eat the pollen or the nectar, and be able to carry away but a small amount of the pollen.

So plants have adapted means to prevent the entrance of these visitors. Some have a sticky ring just below the flowers, and this forms an effectual barrier against ants and like insects. Others have the calyx tube or stems covered with hairs, which may be sticky.

In some flowers, notably those having nectar at the bottom of long spurred petals, the nectar is inaccessible except to large, strong insects, which have a tongue or sucking tube long enough to reach to the bottom of the spur. Other plants have a milky secretion called *latex*. The epidermis in many such plants is very delicate, and is very easily pierced by the claws of insects like ants. Whenever the epidermis is so pierced the latex gushes out and by its hardening holds the insect fast.

132. **Prevention of self pollination.**—It is clear that if plants did not have special adaptation to prevent it, self pollination would often occur. In dioecious and monoecious plants it is impossible, but many perfect flowers have had to provide certain forms of structure, and other peculiarities, to insure cross pollination. Sometimes the position of the stigma is such that pollen from the anther could not reach the stigma unless carried there.

In other flowers the stigma and pollen mature at different times. In some of the flowers the pollen matures first, and in others of the same species the stigma matures first. In other flowers there are stamens and pistils of two sorts, one individual has long stamens and short styles, the other has short stamens and long styles. And in this case, the pollen of the long stamen is active only upon the long pistil, while that of the short stamen is potent only upon the short pistil.

133. **Bird and water pollinated flowers.**—A few flowers are bird pollinated, usually those having long, tubular corollas, into which the long bill of the humming bird goes in search of nectar. The trumpet honeysuckle and gladiolus are instances of this type of pollination. Pollen is, in the case of a few aquatic plants, carried from flower to flower by the water on which it floats.

Only a very incomplete idea of pollination can be given here, and one cannot gather more than an imperfect knowledge of it without actually watching some of the flowers and their insect visitors. Any garden will afford material for many days' study of this topic, and individual flowers should be observed carefully in order to learn their particular adaptation to this end. No flowers will be of greater interest in this study than those shown by our common bleeding heart, garden iris, barberry, and dandelion.

134. **The light relation.**—All plants with the exception of the fungi and a few parasitic plants of other groups, must have light in order that they may carry on their chlorophyll work. (See page 57.) Some may be able to live in strong sunlight, others have learned to adapt themselves to shade conditions. It is essential that not only the outer portions of the plant be exposed to the light, but that every leaf blade, every portion of the green part be exposed in greater or less degree.

So plants have found it necessary to take upon themselves certain adaptations by which all the cells doing chlorophyll work may get their proper share of the light which comes to the plant. These adaptations have affected the position and shape of the leaves and the length and position of the branches of the plant. It is not so essential to know what the names are which are applied to the leaf forms, as it is to know why the leaf has assumed that particular form, and reason for its form can nearly always be found when studying its light relation.

135. **Arrangement of leaves for light.**—The arrangement of the leaves on the stem which has already been studied (see page 50) is an illustration of adaptation to light. In the case of opposite leaves, the pairs are placed at right angles to each other, so that no pair can directly shade the light from the ones below. In the alternate arrangement the leaves are also in vertical rows, but in this case the individual leaves in their adjustment form spirals, so that the third leaf is over the first, or the fifth,

FIG. 14. A group of leaves, showing how branched leaves overtop each other without dangerous shading. It will be seen that the larger blades or less-branched leaves are towards the bottom of the group.

seventh, thirteenth, and so on, is over the first, ample space for light being left between the ones that are directly over each other in the row. If the leaves upon a plant are narrow, there will usually be numerous vertical rows, but if they are broad the number of rows will be few. On the twigs of the elm with its comparatively broad leaves only two rows are found, but the willows with narrow leaves have usually five rows on the stem.

136. **Division of leaf blade.**—The division of the leaf blade is also of great importance in considering the light relation. Many plants, like the yarrow and dog fennel, have the leaves cut into innumerable divisions; this is undoubtedly in order that the light may penetrate the whole plant. Compound leaves with small leaflets represent a similar manner in which some plants have solved the light problem. Plants with broad leaves we find have the lower petioles the longest, the ones above having successively shortened petioles, in order that each leaf may have light exposure. The common geranium will show this arrangement and if one looks down upon the top of the plant, the leaves will seem to be arranged in a pretty pattern, which is known as a *leaf mosaic.*

Many plants show this mosaic arrangement when looked at from other points of view. Wall climbers, exposed to the light from but one side, usually show an interlocked layer of leaves, fully covering the wall, but not shutting off the light from each other. Sometimes none of the petioles of plants will be of any considerable length, but will show the graded lengths, and the plant will form a close, compact body, known then as a *rosette.* The common houseleek is a type of this arrangement, and it is a matter of great interest to note the mathematical nicety with which its leaves are adjusted for light.

137. **Vertical leaves.**—All of the features above mentioned are found usually in connection with leaves that are placed horizontally on the stem. Some plants, however, do not hold their leaves in this position, but the petioles are so turned as to make the leaves vertical on the plant.

The hyacinth, tulip, iris and other common plants show this arrangement, as do also the compass plant, and rosin weed of the prairies, and the prickly lettuce of our roadsides. In this case the arrangement is such that the leaf will receive light more upon the edge than the surface of the blade, and is in the nature of a protection from too intense light. The leaves of the compass plant are often, but not accurately, arranged in a general north and south direction, the faces of the leaves thus receiving the morning and evening light, but not the more intense light of noonday.

138. **Shapes of trees and light relation.**—The effect produced upon the shape of trees by their adjustment to light conditions is often very striking. The evergreens are notably conical trees, that is, have conical outlines. This is due partly to the fact that the lower branches, being most in danger of shading, have carried their leaves out farther to get the light, while the upper ones have not found it necessary to do so. Many trees, aside from the evergreens owe their particular shapes to this same feature, but it is often not quite so evident. Elms and maples have their lower branches the longest, but the branches do not assume great regularitv of position, as do those of the evergreens. In dense forests, where trees shade each other, the trunks often extend to great heights without bearing a single branch, for branches have been unable to live without the light, and only those at the extreme top of the tree have received sufficient illumination for growth.

139. **Movement to light.**—Any one having raised plants in a window garden will be aware of the fact that plants have power to make movements to adjust themselves to the light. The common one-sided shape of the window garden plants is the result of the plant's struggle with unfavorable light conditions. If such a plant is turned around and left a short time, the leaves will invariably turn and readjust themselves for greater light expo-

sure. This arrangement usually takes place within a remarkably short time.

Plants growing in a state of nature are many of them unable to change their leaf positions at all, but some of them change them at intervals during the day, in order to receive more or less light. Instances of this are shown in some compound leaflets, which turn their faces to the sun at some periods of the day, and the edge to it at other times. Many plants when night comes assume a position which is still called the *sleep* position. This is probably to prevent too rapid radiation of heat, rather than as a response to changing light conditions. The influence of light upon the position of the leaves and organs of a plant is known as *heliotropism.*

QUESTIONS

1. What is pollination? What is its object? When and by whom was it proven that plants do not usually fertilize their own ovules?

2. What are the kinds of pollination? Which is the more common method? Are flowers ever self pollinated? How is the violet pollinated? What is cleistogamy?

3. What are the agents of pollination? What plants are examples of wind pollinated plants? What are the characteristics of wind pollinated flowers?

4. When animals are the agents of pollination, is the relation one-sided? Why, in general, do flowers have showy corollas, nectar, and so on?

5. What adaptations for carrying pollen do insects have? What are the characteristics of insect pollinated flowers? How do flowers with regular corollas develop the element of attraction?

6. Do insects visit all flowers indiscriminately? What class of plants is most highly specialized from the standpoint of insect pollination?

7. What is a hybrid? How do florists produce the great numbers of new varieties sent out by them? What can be said of the range of hybridization?

8. How do plants keep off unwelcome visitors?

9. What are some of the adaptations possessed by flowers to prevent self pollination?

10. How are some aquatic plants pollinated? How is the gladiolus pollinated?

11. Why do plants need light? What is meant by the light relation of plants?

12. How are leaves adjusted on the stem for the light? Why is the leaf blade so often much divided? How does a plant with broad entire leaves adapt itself to the light? What is a leaf mosaic? What is a rosette?

13. Why are leaves sometimes vertically arranged on the stem? How does the adjustment to light by trees affect their shape? Why are the trunks of trees in dense forests so often entirely free from branches on the lower portions?

14. To what is due the unsymmetrical shape of plants in a window garden? Why do plants sometimes change the position of the leaves when growing naturally? What is the sleep of plants? What is heliotropism?

OUTLINE FOR STUDY OF PLANT

1. Dicotyledonous or Monocotyledonous?
2. Flower
   - Complete or Incomplete?
   - Regular or Irregular?
3. Calyx
   - a. Gamosepalous or b. Polysepalous?
   - If a. describe its Tube and Border.
   - If b. give Number and Shape of Sepals.
   - Is the Calyx Free or Adherent to the Ovary?
4. Corolla
   - a. Gamopetalous or b. Polypetalous?
   - If a. describe its Tube and Border.
   - If b. give Number and Shape of Petals.
   - To What is it Attached? Color?
5. Stamens
   - Number? United or Not?
   - If United, How?
   - To What Attached?
   - Are the Anthers Innate, Adnate or Versatile?
   - Relative Length of the Filaments?
6. Pistil
   - One or Many?
   - Simple or Compound?
   - How many Cells has the Ovary?
   - Few or many Ovules?
   - Describe the Style and Stigma.
   - Placentation?
7. Inflorescence
   - Solitary or Clustered?
   - Kind of Cluster?

8.	Leaves	Simple or Compound?
		Venation?
9.	Stem	a. Above or b. Underground?
		If a. Woody or Herbaceous? Direction?
		If b. Kind?
10.	Kind of Root?	
11.	Habit Study?	
12.	Pollination	a. Cross or b. Self Pollinated?
		If a. Agent and Proofs?
		If b. Proofs?
13.	Classification	Order?
		Family?
		Genus?
		Species?
		Scientific Name?
		Common Name?

INDEX

C

D

E

These blank pages are supplied to afford a place for the preservation of items of interest gathered from time to time by the student in his study.